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The European Science Notes Information Bulletin (ESNIB) 90-05 is a compilation of reports on recent developments in European science of specific interest to the U.S. research and development community, and is issued in support of the mission of the Office of Naval Research European Office. Issue Number 90-05, in addition to European area news, notes, and abstracts, contains reports in the fields of Acoustics, Atmospheric Electricity, Computer Science, Electronics, and Physics. The value of the ESNIB to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. The ESNIB authors are primarily ONREUR staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the U.S. Army Research, Development and Standardization Group. Scientists from the U.S. who are traveling in Europe may also be invited to submit reports.

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Commanding Officer ..... CAPT Victor L. Pesce, USN
Scientific Director ..... James E. Andrews
Editor ..... Ms. Connie R. Orendorf

ACOUSTICS

ATMOSPHERIC ELECTRICITY

COMPUTER SCIENCE

ELECTRONICS

Although scientifically based, an NDT conference is different in that the interest is not only on developing new techniques, but also on immediate application. The conference is organized by the International Congress on Nondestructive Testing (ICNDT) and hosted by the Dutch Quality Surveillance and Non-Destructive Testing Society.

PHYSICS

SAES Getters is an Italian company headquartered in Milano, Italy. This report emphasizes how SAES capitalizes on research and development within a specialized sector of metallurgical knowledge over a half century.

This conference provided a glimpse of French activities in the field of detonics and high dynamic pressures. Some of the presentations covered gas dynamics, detonation of explosives, hydrodynamic code calculations, equations of state and instrumentation.

This conference discusses effects and applications of shock waves, and high-strain-rate phenomena on materials. The conference is unique as the majority of the participants are from Eastern Europe. Some themes addressed by the author are: explosive welding, hardening, and clodding of materials, Soviet technology developments applications, and compaction of T_c superconductors.

Presentations given at this meeting are discussed. Some subjects are: molecular decomposition studies, reaction pathways and projectile impact, high-pressure studies hotspots, molecular structure and sensitivity, kinetic isotope effect, molecular architecture, and energy output.

The author presents summarized results at the workshop. Principal results discussed at the workshop were the relationship between structure and properties of explosives and mechanisms and by-products of explosive decomposition.

Some presentations at this conference covered internal magnetic fields, aeronomic phenomena, and magnetospheric phenomena.

NEWS, NOTES, AND ABSTRACTS

European Community Adopts Framework Program

by Patricia Haigh, U.S. Mission to the European Committee (USEC), Brussels

Introduction

On April 23, 1990, the Economic and Finance Ministers of the European Community (EC) Council of Ministers (Council) formally adopted without debate the Framework Program of EC activities in research and technological development for 1990-1994. Commencement of this program will overlap (standard procedure) the current research and development (R&D) program.

The EC will provide 5.7 billion European Currency Units (ECU) ($6.4 billion) for the Framework Program and implement it through specific R&D initiatives. The Council and the European Parliament must approve these specific R&D initiatives.

There are thirteen proposals in the following science and technology areas:

- Information technologies
- Communication technologies
- Development of specialized telematic systems
- Industrial and materials technologies
- Measurement and testing
- Environment
- Marine science and technology
- Biotechnology
- Agriculture and agro-industrial research
- Life sciences and related technologies for developing countries
- Non-nuclear energies
- Human resources.

The Council should pass a fourteenth proposal concerning the safety of traditional nuclear fission in summer 1990. A final proposal concerning the technology of nuclear fusion should be transmitted to the Council in September 1990.

Filipo-Maria Pandolfi, new EC Commissioner for Science, Research and Development, Telecommunications, and Joint Research Centers, said that he would consider international cooperation in large-scale projects. The 1987-1991 R&D Framework Program did include a small initiative to provide support for scientists to work at large European research facilities. Pandolfi also announced plans to examine special procedures inspired from the U.S. National Science Foundation for the proposal application system. Announcing the new R&D Framework Program and taking questions from the press, Pandolfi mentioned his recent contacts with the U.S. Administration, including to create a Biotechnology working group.

The EC intends to prepare a study on the entire science and technology (S&T) relationship of the EC to countries and regions worldwide. A draft should be completed in spring 1990 and will include a section devoted exclusively to the S&T relationship between the U.S. and the EC.

Enabling Technologies

The thrust of EC interest in Information and Communications Technologies is as tools for improving industrial competition, economic production, and quality of life. The EC service sector activities already represents 57 percent of community gross domestic product (GDP). Responding to the need for increased information sharing, the EC proposes special emphasis on telematic systems in priority areas of transport, health care, education and training, environmental protection, and special rural area needs.

Industrial and Materials Technologies

The EC reports that manufacturing industries account for nearly one-third of EC GDP. With many small- and medium-sized firms, there is a lot of competition in some sectors and the EC recognizes need for more emphasis on environmentally acceptable production technologies, technical advances relevant to many industries, and on prenormative research.

The R&D proposal will address developing new materials and improving the materials production cycle. In primary materials, research will address improving prospecting techniques impacts of mining on the environment, and waste recycling. In advanced materials, emphasis will be on high-performance materials metals, ceramics, polymers, and composites, and on certain functional materials, including superconductors and magnetic materials.

In design and manufacture, emphasis will be placed on integrating systems such as mechanics, optics, acoustics, and fluid mechanics. The new R&D proposals include both specialized small-scale production techniques and large-scale applications.

In chemicals, the EC proposals emphasize separation technologies, molecular engineering catalysis, and surface science.

Natural Resources Management

The EC views its role in environment as supporting global efforts for research and management, and as a research support arm of the European Environmental Agency. Priorities are

- Global change program
- Environmental engineering
- Socio-economic aspects of environmental management
- Integrated research projects

In Marine S&T, priorities are

- Marine science
- Coastal engineering
- Marine technologies.

In life sciences and technology, the EC hopes to stimulate Europe's diverse laboratories to provide a research base for emerging bioindustries.

- Biotechnology - molecular studies, structure and function of essential organisms, ecology and biological populations
- Agriculture and Agroindustrial Research - agriculture, forestry, and aquaculture production; agricultural and forestry additives (e.g., pest control); primary biology materials treatment; and product utilization
- Biomedical and Health Research - harmonizing clinical protocols, studying social impact illness, and analyzing human genome
- Life Science and Technology for Developing Countries - agriculture; medicine, health, and nutrition.

The two main energy issues for Europe are its dependence on imports (47 percent) and damage to the environment caused by energy production and consumption. The European Commission (Commission) will address needs for security of supply and economically viable clean technologies. In non-nuclear energy, the proposal includes modeling and analyzing; utilizing fossil fuels; renewable energy; and building design and materials-related issues.

Intellectual Resources Management

Compared with the U.S. and Japan, Europe has few R&D researchers. The Commission proposes to develop networks of centers of excellence, organize special training sessions at these sites, and facilitate scientist mobility across countries, sectors, and disciplines. Special emphasis areas will include

- Advanced fundamental research methods in exact and natural sciences, including mathematics emphasizing complex nonlinear systems, condensed materials, and molecular systems
- Relationship between research, technological applications, and social/economic science supporting European competitiveness.

ACOUSTICS

Sea Acoustics Symposium - Satellite to the ICA '89

by David Feit, the Liaison Scientist for Acoustics and Mechanics in Europe and the Middle East for the Office of Naval Research European Office. Dr. Feit is on leave from the David Taylor Research Center, Bethesda, Maryland, where he is a research scientist in the Ship Acoustics Department.

Introduction

The Sea Acoustics Symposium, a satellite meeting to the 13th International Congress of Acoustics, was held in Dubrovnik, Yugoslavia, September 4-6, 1989. Dubrovnik, a medieval city rich in culture and historical monuments, with breathtaking views of the Adriatic Sea, was an excellent retreat for this gathering of specialists in underwater acoustics. Many of us came to Dubrovnik after a hectic period in Belgrade where the main congress had just been completed. A report on the 13th International Congress of Acoustics by Laszlo Adler appears in this issue on page 6.

This meeting had a much smaller attendance, approximately 150 scientists, as opposed to more than 700 in Belgrade. Many of the attendees were from former Eastern Block countries. I was impressed by the fact that several very high ranking Soviet acousticians were among the participants. As I have mentioned in previous reports on meetings that I have attended during my tenure at ONREUR, more Soviets are appearing at meetings and much more consistently than ever before.

Each of the 3 meeting days began with an invited talk, and the final presentation of the meeting was a summary report of the meetings' highlights. In addition to the three invited talks, there were 24 contributed papers presented. Five were from the U.S.S.R., which I thought was an unusually large number, especially considering the potential sensitivity of the subject matter.

Although the sessions were not organized around special themes, the talks can be categorized into the following:

- Underwater sound propagation
- Scattering from naturally occurring boundaries and inhomogeneities
- Scattering from man-made objects.

I will discuss the invited talks and representative presentations from the contributed papers.

Plenary Lectures

D. Guan, Institute of Acoustics of the Science Academy, Beijing, People's Republic of China (PRC), gave the first invited talk of the meeting. Guan spoke about recent progress in shallow water underwater acoustics. Because of their interest in shallow water problems, much of the effort is related to the influence of the sea bottom as it affects the optimum frequency for long-range transmission. Interestingly enough, they find that experimentally in shallow waters off the coast of PRC, they have not been able to observe an optimum frequency. Guan suggested several possible explanations, each of which he related to inadequate knowledge about the properties of sea bottom sediments.

Other topics that he surveyed were, remote sensing of the sea bottom parameters, the average sound field in a duct, long-range observation, mode filtering, and the effect of internal waves on sound transmission. From his talk and the references cited, I would conclude that the PRC effort in underwater acoustics, although somewhat limited in scope, is certainly cognizant of current western efforts and is being directed rather effectively under Guan's leadership.

The second plenary talk was given by V.A. Akulichev, Chief Academic Secretary of the Far Eastern Branch, U.S.S.R. Academy of Sciences, Vladivostok, one of the high-ranking Soviet acousticians at the meeting. He discussed the possibility of determining large-scale sea water inhomogeneities using insonification.

The examples presented were related to a sound propagation study through a warm anticyclonic oceanic eddy in the northwestern Pacific Ocean. The results shown were rudimentary and based on measurements along tracks with movable sound sources and receivers. The source frequency was at 232 Hz with signal reception at a 300-meter depth (measurements were made at several other depths down to and including 1,000 meters) and projector towed at 100-meter depth.

Without mentioning any specific undertakings, Akulichev alluded to the difficulties inherent to large-scale acoustic tomography schemes requiring large numbers of calibrated projectors and accurate measurements made by receivers. I would have been interested to learn if the Soviets have or are planning to conduct any large-scale acoustic tomography experiments, but Akulichev did not discuss this. All his references were to publications by Western investigators, primarily from the U.S.

The last of the plenary lectures was presented by J. Ripoche, University du Havre, Le Havre, France. Ripoche discussed the signatures of passive and active targets by using resonance spectra. The talk reviewed an experimental technique called the "Method of Isolation and Identification of Resonances (MIIR)," introduced in 1981 (Maze, 1981).

As an aside, and not really directed towards this particular presentation, this subfield suffers from a plethora of acronyms that have been introduced over the years. Several investigators in this field have fallen into the habit of giving names to approaches as if to raise their scientific merit and thereafter referring to them by acronyms, a style that can be confusing.

As I understand it here, MIIR is associated with the analysis of experimental data designed to both isolate and identify resonances that can be predicted theoretically for the scattering of sound by certain idealized shapes. For example, when such a target is insonified by a long rectangular pulse with a distinct carrier frequency, the scattered field consists of three distinct phases. And if the carrier frequency is close to one of the body resonance frequencies, the decaying sound field in the third phase rings at this frequency. If the carrier frequency were not a resonance frequency, the ring-down effect would not occur.

Other examples of the means by which experimental measurements are used to identify and isolate resonances are presented, including bistatic measurements. This work offered a very concise, but still comprehensive review of the experimental techniques used in scattering by elastic objects. However, I am still not sure what the author means in his title by the distinction between passive and active targets.

Contributed Papers in Underwater Sound Propagation

Two sessions were devoted to underwater sound propagation, comprising the first afternoon and second morning of the conference.

H. Überall, Catholic University of America, Washington, D.C., speaking on behalf of himself, J. Arvelo, Naval Surface Warfare Center, White Oak, Maryland, and M. Talmant, University of Paris, France, discussed the effects of including ocean bottom shear waves in underwater sound propagation. They have performed calculations allowing for vertical sound speed gradients (linear variation in layers), range-dependent, coupled mode theory, and shear and absorption corrections in the layers representing the ocean bottom. They conclude that radiation into the bottom is caused by coupling between trapped and radiation waves. There were no comparisons with calculations made by other authors.

The French contribution to the propagation session was given by D. Juvé, Ecole Centrale de Lyon, Ecully, France. He discussed the different ray systems associated with various parabolic approximations, including the standard parabolic and wide-angle parabolic approximation. For the case of a bilinear sound profile, he showed the ray trajectories and made estimates of the transit time along eigenrays. These were compared to those obtained from the exact Helmholtz equation rays. In general, the wide-angle approximation results are very close, while for the standard parabolic approximation there can be significant transit time errors when the emission angle and the sound speed gradient are large.

M.A. Ainslie, the SEMA Group, New Malden, U.K., talked about locally averaged transmission loss in a quadratic duct. Detailed transmission loss calculations for underwater sound ducts usually reveal a highly oscillatory range dependence. This paper presented a technique whereby a fairly smooth range average is obtained analytically before the computer time-intensive mode sum calculations are required. Errors are of course introduced, but their genesis is well understood and corrections can be applied.

Other presentations in this session included works by L. Fishman, Colorado School of Mines, Golden; R. Zhang and Z. Lu, Shanghai Acoustics Laboratory, Shanghai, PRC; and A. Voronovich, Shirshov Institute of Oceanology, Moscow.

The second session on underwater sound propagation began with another Soviet contribution. A.A. Moiseev, Shirshov Institute of Oceanology, Moscow, discussed the modeling of the low-frequency noise field structure in the vicinity of an ocean front. His three-dimensional ocean model assumes that the wavelength is small compared to the large horizontal scale of the ocean inhomogeneities permitting him to make the adiabatic assumption, and neglect mode coupling. He then models an ocean front as a plane separating two different regions with distinct hydrologic parameters depending only on the depth. Using this model, he finds that the ocean front substantially distorts the intensity field structure predicted by the layered medium theory.

This paper was one of three contributions from the Shirshov Institute. At a recent conference in Brighton, U.K., called "Oceanology '90," this institute was similarly well represented with three contributions and a planned appearance of one of its oceanographic vessels which,

unfortunately, never materialized. V.A. Mozgovoi, also of the Shirshov Institute, gave another paper in this session presenting some interesting facts on the migration behavior of sound scattering fish. These were determined from measured differences in scattering strengths at different frequencies, which are attributed to differences in the size of the fish swimbladders and whether or not they "pump" their bladders before migration.

T. Stanton, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, gave a paper on the modeling of sound scattering by spherical and elongated objects, with application to sound scattering by marine organisms. He compared his model calculations made for small bent cylinders with measurements made on preserved euphasiids, which, from their description, looked like shrimp.

Scattering and Reflection From Underwater Boundaries

This session had several papers that focused on the problems of obtaining characteristics of the ocean bottom using inverse methods on experimentally obtained sound reflection data. The contribution by Q. Wang and R. Zhang, Shanghai Acoustics Laboratory, Shanghai, outlined the difficulties in extracting bottom loss parameters from the theory of smooth-averaged sound fields (Zhang, 1981). He presented examples using both numerical simulation and experimental data.

There were two papers presented by a group of investigators from the Hydroacoustics Laboratory, Instituto de Acústica, Madrid, Spain. The investigators are C. Ranz-Guerra, P. Cobo-Parra, and R. Carbó-Fité. Their contributions dealt with signal processing algorithms used to filter out the roughness contribution of the normal incidence bottom reflected signals and assessing their performance using experimental data obtained in a 45-meter deep reservoir.

G. Wendt, Wilhelm Pieck University of Rostock, German Democratic Republic (GDR), presented the details of a data acquisition and processing system used in the hydroacoustic localization for sediment detection. Such a system has been used in characterizing the bottoms in various Baltic Sea locations. They have achieved a penetration depth of 20 meters and a resolution better than 0.3 m.

Other papers in this session reviewed the different types of survey vessels used in seismic exploration of the seabed, and another talked about a hydroacoustic data processing system for fish stock assessment.

Scattering From Man-Made Objects

This session, as well as in the preceding invited lecture, was completely dominated by French contributions. Contrary to a recent trend in which French investigators have been more willing to present their talks in English at international meetings, two of the papers were presented and published in French. French, together with English and German, were the official languages of this meeting.

The first paper, authored by a group from the Universite du Havre, including C. Lenoir, P. Rembert, J.L. Izbicki, G. Maze, and J. Ripoche, presented the results of experiments designed to determine bottom parameters assuming the bottom can be characterized as homogeneous layers. Some experimental results obtained from ensonifying a PVC plate were shown, together with a short discussion of how the measurements are to be utilized to determine the parameters of the plate. Exploitation of these techniques is currently underway.

M. Zakharia, P. Flandrin, and F. Magand, Laboratoire de Traitement du Signal, Lyon, France, wrote a paper that discussed different signal processing approaches to study the scattered field from elastic targets. One approach uses a time-frequency type analysis (Wigner-Ville distribution) while the second leads to a constant Q-analysis; i.e., all the filters used must have a constant time-bandwidth product. This latter constraint requires that the ensonifying signal be of a very specific type. These approaches are said to be able to considerably reduce the amount of information needed to characterize a target. There appears to be a lot of activity at French research institutions dedicated to advanced signal processing techniques applied to acoustical signals.

Of the remaining two papers in this session, one was a theoretical development related to a new intermediate background for the S Matrix scattering theory for elastic objects in water, while the other treated the experimental observations of reflection from an oval-shaped tube.

H. Überall provided the summary technical report to the meeting, and he performed remarkably well, managing to make one or two congratulatory remarks about every one of the more than 20 talks presented at this satellite congress.

Summary

This meeting, much smaller in size than the main congress, managed to bring together scientists from both east and west to discuss various problems in underwater acoustics, a rare occurrence in the not-so-distant past. The opportunity to interact with and hear discussions on underwater acoustic propagation from such highly esteemed acousticians as Brekhovskikh and Lyamshev, U.S.S.R., was useful to all, and further re-enforces the new era of openness with the U.S.S.R. that the world is now experiencing.

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Zhang, R., "Smooth-Averaged Sound Field in Shallow Water," *Acta Oceanologica Sinica 3*, (1981), 535-545.

13th International Congress on Acoustics Report

by Laszlo Adler, Taine McDougal Professor of Welding Engineering and Engineering Mechanics and Director of the NDE Program, Welding Engineering Department, The Ohio State University.

Introduction

The 13th International Congress on Acoustics (Congress), the largest international forum on acoustics, was held in Belgrade, Yugoslavia, August 24-31, 1989. The 8-day conference was held at the Sava Center in New Belgrade, one of the largest conference halls in Europe. The Congress, which meets every 3 years, is organized by the International Commission on Acoustics (ICA). There were 991 delegates from 38 countries. The largest delegation came from France with 161 people, followed by Japan with 136, Yugoslavia with 115, the U.S.S.R. with 104, the U.S. with 93, and the Federal Republic of Germany with 63. Over 500 presentations were divided into 13 parallel sessions each day through the conference (see Table 1).

Table 1. Congress Session Topics

- Physical Acoustics
- Aero Acoustics and Atmospheric Sounds
- Architectural and Building Acoustics
- Speech Communications
- Physiological and Physchological Acoustics
- Musical Acoustics
- Noise
- Shock and Vibrations
- Transduction
- Measurement, Instrumentation, Signal Processing, and Statistical Methods
- Bioacoustics
- Ultrasonics, Quantum, and Physical Effects
- Underwater Acoustics

Satellite Symposia

Two satellite symposia were held after the Belgrade conference: (1) Electroacoustics in Zagrab, September 1-3, 1989, and (2) Sea Acoustics in Dubrovnik, September 4-6, 1989. See Sea Acoustics Symposium by David Feit on page 3.

Congress Sessions

Although there were 13 parallel sessions, those that were relevant to Office of Naval Research-funded (ONR) program were Session 1--Physical Acoustics, and Session 12--Ultrasonics, where two ONR papers were presented. The papers were entitled, "Guided Interface Waves in Adhesive Layers" by Peter B. Nagy and Laszlo Adler, and "Interface Characterization with Ultrasonic Waves" by Laszlo Adler and Peter B. Nagy.

Computer Modeling for Research in Nonlinear Acoustics, Professor Akira Nakamura, Osaka University. There are potential applications in nondestructive evaluation (NDE), especially in strength-related problems; e.g., interface studies between fiber and matrix. The two basic principles used in his computer simulation are nonlinear finite amplitude wave distortion and linear attenuation and velocity dispersion. I was especially interested in talking to Nakamura because I visited him in Osaka in 1987 when he just started his computational program in this area. Nakamura presented several examples, including soliton formation process and parametric amplifications with some potential in NDE.

Optical Generation and Self-Action of Nonlinear Acoustic Waves, Professor Rudenko, Moscow University. Because of increased interest in the NDE community in noncontact transducers, it was very informative to hear theoretical and experimental results presented by Rudenko on laser generation of ultrasonic waves. The three main areas discussed were:

(1) Intense, short acoustical pulse generation by absorption of laser radiation and the use of these pulses to measure acoustic parameters and their variations with material properties

(2) Resonant interaction problems in acoustics; e.g., harmonic generators, parametric amplifiers, and other devices for frequency change

(3) Acoustic beams' self-action and -focusing effects, which are the most fundamental acoustic nonlinear effects for bounded beams.

High-Power Ultrasonics Theory and Experiment, L. Bjorno, Denmark. This method has many applications to industrial processes, including joining materials, especially plastics and composites. The method, combined with some low intensity ultrasonic techniques, could be used to monitor the quality of the joining process.

Acoustique et Physique Du Solide Nouvelles Convergences 100 Ans Apres La Naissance De Leon Brillouin, Andre Zarembovics, Universite Pierre et Marie Curie,

Paris. This paper discussed the many contributions of Brillouin to ultrasonic study including: (1) wave propagation through periodic structures; (2) Brillouin scattering, which is an important tool in studying layered material (layer thickness in the nm regions); and (3) diffraction of light through ultrasonic waves which, 60 years after its discovery, plays an important role in many acousto-optic devices.

The other six plenary sessions addressed the different topics in current acoustic research related to noise and bioacoustics which will not be addressed here, but further information is available by obtaining the five-volume proceedings. Some additional papers on the new technological areas are discussed below.

Several papers addressed the issue of acoustic chaos which has had remarkable developments over the last 10 years in various branches of science including acoustics.

Chaos, Professor Lauterborn, Federal Republic of Germany, a leading expert on nonlinear bubble dynamics and a promoter of this new field presented some very fundamental ideas and methods of chaos physics. This new language and its basic tools were presented and illustrated by examples in acoustics; e.g., a bubble in water driven by a sound field and other nonlinear oscillators. I had an interesting conversation with Lauterborn after his lecture (we worked together in the Acoustics Institute in Gottingen some 24 years ago). His ideas are that the methods invented for chaos characterize irregular motion from deterministic systems more specifically than from their Fourier spectra, which is a linear concept. Chaos concepts will find their applications in the area of nonlinear oscillating systems, hence in nonlinear acoustics.

Nonlinear Dynamics of Simple Cavitation Bubbles, R. G. Holt, National Center of Physical Acoustics, Oxford, Mississippi, Holt raised the question, "Which of the nonlinearities is responsible for chaotic results: the nonlinear coupling between bubbles in the field, or the nonlinear oscillations of the separate bubbles?" The question, "Do single bubbles exhibit chaos?", has not been satisfactorily answered.

Boundary Acoustic Nonlinearities in Solids, Solodov, Moscow University. Solodov introduced mathematical formalisms of acoustic nonlinearities of surfaces and interfaces which have numerous applications in geophysics, acoustics, and nondestructive evaluation. Vertically polarized shear waves with large amplitudes were used to study nonlinear reflection at a layer-substrate interface.

Velocity Dispersion and Energy Location of Stoneley-Scholte Waves in Layered Media, Defebvre, Pouliquen, and L.M. Moulrale, University of Lille, France. This paper developed formalisms to calculate velocities for dispersion curves as a function of frequency times thickness for N-layered solid immersed in liquid and made numerical evaluations for Al-Ni and Cu-Plexiglass. The name Stoneley-Scholte is somewhat difficult to interpret (Stoneley waves are waves between two solids and Scholte waves are homogeneous waves at liquid solid interfaces), and we are using the name Generalized Lamb waves for these wave types. I have discussed these problems with Professor Defebvre.

Self-Consistent Justification of Nondestructive Evaluation Method Using Surface Acoustic Wave, Chenin, Pouliquen, and Defebvre, University of Lille. This paper discussed possibilities to obtain elastic constants from ultrasonic surface wave measurements in layered materials.

Comments

The 13th International Congress on Acoustics is still the broadest world-wide forum on acoustical research. Clearly, the participants brought a large variety of new and old research topics in many branches of acoustics. Because of its location in Europe, it brought together scientists from both Eastern and Western countries. On the positive side, the large number of U.S. participants had the opportunity to exchange information with scientists from 35 other countries. On the negative side, because of the large number of parallel sessions (13 each day), it was difficult to coordinate attendance because of time conflicts.

ATMOSPHERIC ELECTRICITY

International Workshop on Global Atmospheric Electricity Measurements

by Dr. Reinhold Reiter, Chairman, Subcommission II, International Commission on Atmospheric Electricity

Background

L.H. Ruhnke, Naval Research Laboratory (NRL), Washington, D.C., and H.F. Tammet, Tartu State University, Estonia, U.S.S.R., discovered (Ruhnke and Tammet, 1983) that synchronous variations within less than 1 hour, and down to nearly 1 second, of the Maxwellian atmospheric electric current density occur at Waldorf, Maryland, and Vilsandi, Estonia. Since then, interest has increased in such simultaneous recordings.

First, Lothar H. Ruhnke initiated a cooperation between the NRL, Washington, D.C., and Stanislaw Michnowski, Institute of Geophysics of the Polish Academy of Science, Warsaw, to establish a suitable antenna also on Spitzbergen (Svalbard) for coordinated atmospheric electric current measurements over very long distances and also in the auroral area. Thus, possible effects of solar events on the atmospheric current also should be studied.

After this first step, it became obvious that this type of investigation concerns the global atmospheric electric current in general, and that a more extensive international participation would be desirable. Such an intensified global cooperation requires agreements concerning the selection of localities and equipment of representative stations, and on methods for recording, processing, storing, and exchanging data. To this end, an international workshop appeared to be the most desirable next step.

International Workshop on Global Atmospheric Electric Measurements Organization and Task

The International Workshop on Global Atmospheric Electricity Measurements (GAEM) was planned by the International Commission on Atmospheric Electricity (ICAE), a commission of the International Association of Meteorology and Atmospheric Physics, L.H. Ruhnke, President. Subcommissions are Global Circuit and Solar Terrestrial Relationships, R. Reiter, Chairman; and Standards, Methods, Applications, H. Dolezalek, Chairman. The GAEM was also sponsored and hosted by the Institute of Geophysics of the Polish Academy of Sciences (Academy). The Academy provided meeting rooms, equipment, and accommodations in its facility at Madralin near Otwock in Poland. S. Michnowski was Chairman of the local organizing committee.

The main task of GAEM was to produce a generally accepted document defining the objectives and approach of the GAEM program and of the participation in the International Geosphere/Biosphere Program (IGBP) and the Solar-Terrestrial Energy Program (STEP). The document, presented as an Addendum to this report, was also to serve as a platform for organizing and conducting the world-wide network of measuring stations for atmospheric electricity parameters and of a system for determining and alerting on priority periods and methods of measurement and analysis.

Program and Participants

The participants and home countries were Poland - 15, the U.S.S.R. - 9, the U.S. - 7, India - 2, and one each from Bulgaria, Federal Republic of Germany, Finland, Mexico, Sri Lanka, Sweden, and the Netherlands. The geographic location of Madralin, near Warsaw, allowed the participation of a relatively large number of colleagues from Eastern countries.

After the opening address by Professor Teisseyre, Polish Academy of Science, and the welcoming addresses by H.L. Ruhnke, R. Reiter, S. Michnowski, and H. Dolezalek, the first day included 25 short presentations given in the following four sessions:

- General Problems of the Global Electric Circuit, R. Reiter, Chairman
- Fluctuations of Atmospheric Electric Parameters Measured at the Earth Surface, S. Anisimov, Rejon, Borok, Chairmen

- Observations of the Atmospheric Electric Elements Above the Troposphere, E.A. Bering II, Chairman
- Schumann Resonances, L.H. Ruhnke, Chairman

Based partially on those presentations, a general discussion was held on the second day to obtain a consensus on how to approach organized international cooperation on the most important problems of the global atmospheric electric circuit. H. Dolezalek condensed the complex aspects and prepared a draft for the discussion.

The following were established:

- Coordination Board, L.H. Ruhnke, Chairman
- Consulting Committee on Definitions, Standards, Measuring Systems, H. Dolezalek, Chairman

The fundamental document was prepared by Ruhnke, Dolezalek, and Reiter, presented and discussed. After the workshop, it was formulated and distributed by L.H. Runke for further discussion (see Addendum).

Conclusions

Stimulated by new observations of simultaneous and fast variations of the atmospheric electric current, observed at stations separated by distances in the order of one third earth circumference, the interest in the global atmospheric electric circuit and in the Maxwellian currents; i.e., including the displacement currents, in or parallel to this circuit has strongly increased. Also, other recent results of investigations in solar-terrestrial relations based on atmospheric electric observations have contributed to this renewed interest (Reiter, 1989).

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Addendum

A plan of Research Cooperation Coordinated by the International Commission on Atmospheric Electricity, Subcommission II on Global Circuit and Solar-Terrestrial Relationships.

Background. Atmospheric electricity measurements often include information on local, global, and extraterrestrial processes in such a way that the dynamics of these processes is assessed in real time over a very wide temporal range. Separation of these groups of information is generally difficult and a subject of research. These atmospheric electricity relations can be used as indicators for elements of other atmospheric and space parameters and processes, many of which are directly or indirectly of interest to IGBP and STEP.

Approach. The program will use a network of measurement stations, including a dense network at high latitudes to collect coordinated data on atmospheric electricity variables. Analysis of the data will include other appropriate information such as meteorology, air pollution, cosmic rays, and solar events using surface, aircraft, balloons, and rocketborne sensors to establish and verify theoretical concepts and models, and to create theoretical models necessary for distinguishing global from local effects.

Objective. The objective of the Global Atmospheric Electricity Measurement Program (GAEM) is to investigate in detail the local/global and the extra terrestrial/global/local relationships among those elements that are relevant to the International Geosphere Biosphere Program (IGBP) and the Solar-Terrestrial Energy Program (STEP) of ICSU. Among these are:

- Understanding and identifying solar-terrestrial influence on surface atmospheric electricity variables
- Separating and identifying local and global effects in surface observations
- Establishing a global network of atmospheric electricity stations with digital recordings, possibility of high time resolution, and communication for data exchange. Utilize existing stations as appropriate.

Main Research Tasks

- Perform atmospheric electricity research in the time domain of one second to one solar rotation period. Related data on magnetic fluctuations, solar events, and cosmic rays occur in this time domain. Measuring techniques to separate global and local components also work well in this time domain.

  Quantitative techniques of time series analysis will be applied extensively, requiring the use of digital data recording techniques. The study of statistical properties of atmospheric electricity noise (agitation) in the planetary boundary layer will be an object of further experimental and theoretical studies.
- Extend the existing concepts of the global atmospheric electricity circuit by enhanced consideration of meteorological processes, ionospheric dynamo processes, magnetospheric sources, ionization, and attachment processes.
- Investigate the influence of natural and anthropogenic sources on the atmospheric electricity parameters which serve as indicators of interest to IGBP.

Operational Plan

- A Coordination Board was established to coordinate between participating stations and to assist the Alert and Data Centers.
- An Alert Center will be established in the U.S. and will use alert criteria such as forecasted substorms, solar flares, coronal hole ejections, cosmic ray variations, and special measurement campaigns including scheduled balloon and rocket launches. Furthermore, alerts will be issued based on the International Geophysical Calendar and special periods determined by the Coordination Board. Communication will be by telephone, telex, telefax, or special messages through the World Solar Forecast Center. At least one measurement alert per month (but not more than one alert per week) will be issued.
- The data from the network will consist mainly of two types: (1) hourly averages of electric field, conductivity, current density, meteorological background, and (2) measurements at intervals at less than one hour in digital form for limited time periods of Maxwell currents and electric field in connection with solar and magnetospheric events. For the hourly averages, the World Data Center at Voeikov Main Geophysical Observatory, Leningrad, U.S.S.R., will be used. For high time resolution data, a new data center will be established in the U.S.
- A committee of the Coordinating Board will be established to develop criteria for the selection of additional sites, and to prepare a list of urgently needed new sites.

Definitions, Standards, Measurement Systems. A consulting committee has been established to write a technical protocol that will include the following: detailed definitions of terms, standards of instruments and measurement systems, data exchange media and data formats, data sampling rates and durations, and other related matters. A preliminary draft of this protocol will be assembled by March 1990, and a final document will be completed by May 1990. This consulting committee consists of: H. Dolezalek (Chairman), S.V. Anisimov, E.A. Bering III, J. Drzewiecki, E. Knutsen, H. Tammet, N.C. Varshneya.

Rules of Participation. Any participant has the right for all the data of all other participants free of charge. For any published data, producers will be given credit. An appropriate station description must be on file at the Coordination Board and related Data Center.

Time Plan. This program starts as soon as possible but not later than to coincide with schedule of STEP.

Network of Stations. At the workshop, a preliminary list of stations to participate in the GAEM Program has been established. Some are already in operation, others are under development. Further participation is solicited.

Contact With Other Organizations. The Coordination Board will maintain contact with ICSU, WMO, and SCAR, and will established coordination with STEP and IGBP from which it seeks endorsement. The GAEM will also maintain contact and coordinated activities with appropriate national programs such as the "Global Circuit Commission" of the U.S.S.R. and the "All-India Coordinate Program on the Global Circuit."

Further Actions. The GAEM Document is being distributed to all participants of the Madralin Workshop for final acceptance. The Coordination Board has become active by correspondence and intends to hold planning meetings in the near future. Existing recording stations that fit the GAEM tasks should be adapted to the GAEM requests as soon as possible. The door is open for further participants. For more information, contact:

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COMPUTER SCIENCE

Supercomputing Europe '90

by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for Industrial Assessment in Computer Science and Telecommunications.

Introduction

Supercomputing Europe '90 was the second European Exhibition and Conference organized by Royal Dutch Fairs. The conference was held in London, January 10-12, 1990, and had an international attendance of about 165 participants coming from 14 Western European countries, and Iran, Israel, Japan, Saudi-Arabia, U.S., and U.S.S.R.

Speakers came from the U.K., Federal Republic of Germany (FRG), France, U.S., and Japan. I attended the first 2 days of the conference and I present summaries of papers given here. Most major suppliers of supercomputers, mini-supercomputers, and some software companies had equipment or products on display.

One important event was the launch by Intel of the iPSC/860 system that is based on the i860 microprocessor rated at 60 million double-precision, floating-point operations per second. Based on this, the iPSC/860 can have a peak performance of 7.6 Gflops and will cost $3 million for the maximum of 128 processors. Thus, the cost per floating-point operation is $0.25.

Summaries

The Challenge of the Large Parallel Processors in Europe, Keynote Speech, Dr. Brian Oakley, Chairman, Logica, U.K.

Oakley began his talk with a discussion of automated chess, giving key dates and events marking its progress:

- 1944 Work of Alan Turing
- 1950 Writings of Claude Shannon
- 1953 Donald Michie (the chess game involves 64 squares and 70 rules leading to 10(exp 15,790) possible games
- 1957 Herbert Simon predicted that a computer would eventually be the world champion in chess
- 1968 David Levy offered a challenge that he would not be beaten by a computer within 10 years
- 1978 Chess 4.5, a computer program, lost to Levy
- 1983 The computer program "Belle" became the computer champion, not the world champion, and held the title until 1984
- 1984 "Cray Blitz" became computer champion and held the title until 1989
- 1989 "Deep Thought" became the computer champion
- 1989 Hsuing Hsu predicted that a computer would be world champion within 10 years
- 1989 David Levy lost to "Deep Thought"
- 1989 "Deep Thought" lost to Kasperov.

So that, as of now, no computer program can be classed as world champion at chess.

Chip technology is one of the driving forces for computer technological development. Performance of several available technologies is given below in Table 1.

Table 1. Computer Technology Development

	Present		Future	
Technology	Clock Speed	Gates	Clock Speed	Gates
ECL	600 MHz	1,500	1,000 MHz	2,000
CMOS	200 MHz	200,000	250 MHz	4 million
GaAs	500 MHz	5,000	5,000 MHz	10,000

The technology of the Cray 3 will be Gallium Arsenide (GaAs). After the chip is made, there still remains a major engineering problem of implementing the chips into a system. There will be a GaAs version of AMT's Distributed Array Processor (DAP) and also the computer being developed by Steve Chen will use GaAs.

In the field of personal computers (PCs), remarkable progress has been made in performance as indicated in Table 2.

Table 2. Personal Computer Performance

Date	Speed
1983	0.3 MIPs
1989	1.0 MIPs
2000	100 MIPs projected

On the question of what is a supercomputer, Oakley said that the U.S. Department of Commerce has defined it as one with speed greater than 160 Mflops and costing more than $10 million. He said, "I would class it as around the top 10 percent of the pyramid of performance at any given time."

The progression of supercomputers is given in Table 3.

Table 3. Supercomputer Progress

Date	Model	Speed	Number
1976	Cray 1	190 Mflops	1
1982	Cray X-MP	710 Mflops	4
1985	Cray 2	1,400 Mflops	4
1988	Cray Y-MP	2,000 Mflops	8
1990	Cray 3/C90	16,000 Mflops	16
1995	Cray 4/C95	100,000 Mflops	64

At the present time, there are about 400 installed Cray-like supercomputers; 235 are actually Cray machines. There are about 196 in the U.S., 106 in Japan, and 93 in Europe. Of the European ones, 25 are in the U.K., 22 are in France, 24 are in FRG, and 22 are in remaining Europe.

The challenge to Cray comes from several sources. These include the Cray-like systems from Japan: NEC, Fujitsu, and Hitachi; the massively parallel systems: Thinking machines, AMT and others; mini-supercomputers: Convex, Alliant, DEC, and powerful workstations.

Now, looking at Europe, the market in 1990 will be about $13.5 billion. There will be an impact on U.S. sales by the U.S. regulations on export of supercomputers. Another influence is the trend toward general purpose symbolic/numeric machines. The European Community (EC), through the European Strategic Programme for Research and Development in Information Technology (ESPRIT) program, is taking a leading role in support of developments. The EC is now supporting three approaches:

1. Genesis combines the work in France on the Isis project and the Suprenum project in FRG.

2. European Declarative Systems (EDS) is a development program carried out in Munich, in a laboratory, involving participation of International Computers Limited (ICL), Bull, and Siemens, as well as several universities.

3. Tropics is an object-oriented system under development and involving Philips, Thomson, and Olivetti.

However, there is good reason to believe that there will continue to be a need for Cray-like systems. The installed memory of such systems has increased more than 500 times during the 1980s, and the installed processing power has increased more than 70 times.

Supercomputing with Transputers, Professor David Wallace, University of Edinburgh, U.K.

The work at the Edinburgh Supercomputer Centre began with a shared ICL DAP in 1980 and a dedicated DAP was installed in 1982 after we had received £180,000. In April 1986, we obtained a Meiko Computing Surface, based on 40 T414 transputers costing £170,000. In September 1986, we asked for £4.4 million to upgrade the Computing Surface, and by July 1987 we obtained £2.3 million that enabled us to proceed with the upgrade (see Table 4). We began with 40 T800 transputers and now have 400 T800 transputers. Funds being made available for the future will permit further upgrading and the development of new applications along with increased staff.

Table 4. Meiko Computing Surface Contributors

Department of Trade and Industry	£1,114,000
The Computer Board	£ 575,000
The Science and Engineering Research Council	£ 400,000
The Meiko Company	£ 770,000
Industrial Affiliates	£ 800,000
Edinburgh University	£ 102,000

Currently, installed hardware is: 400 T800 transputers; 2.7 Gbytes of high-speed memory; 6 Gbytes of disc memory; and 4 graphics stations.

Since the Computing Surface was installed, usage of the center has increased 70 percent, and the availability of the system has been more than 95 percent. We now have more than 300 external users.

In processing Fortran or C languages, a single T800 node performs at about 0.7 Mflops; using the language Occam, its performance is about 1 Mflop; and on basic linear algebra applications it performs at about 1 Mflop.

Among the applications with which we have worked, some are provided in Table 5.

We plan to install a system with 256 processors using the Intel i860 chip.

Table 5. Applications

- Using fractals to develop images, including the image of a planet
- Using cellular automata for fluid flow
- Simulating various chemical processes; e.g., a distillation column
- Using dynamic relaxation analyzer.

Supercomputer Software from ODIN, Professor A. Schreiner, University of Karlsruhe

ODIN stands for Optimale Datenmodelle und Algorithmen für Ingeneur-und Naturwissenschaften auf Hochstleistungsrechnern.

The University of Karlsruhe has a Siemens VP400 (Fujitsu). Our goal is to develop optimized applications software for the Siemens VP system. This includes optimizing of standard applications, developing of new applications, and developing distributed applications over a network of processors.

Applications with which we are working are provided in Table 6.

Table 6. ODIN Applications

- Finite element analysis
- Fast Fourier Transforms
- Random number generation
- Development of a utilities library
- Basic Linear Algebras (BLAS) applications
- Numerical Algorithms Group (NAG) library
- Linear Algebra Pack
- ADINA and FIDAP (finite element packages).

Optimizing the BLAS techniques included: unrolling, optimizing of memory access, introducing buffers, and switching between different algorithms.

An example of a new application we have developed is a finite element program for solving large linear static and time-dependent-finite element problems. The elements are first separated into groups of the same shape. Then elements not adjacent to each other are handled in vector mode, and finally a linear equation solver is used.

Integrated Design, Analysis, and Optimization via Supercomputer, Mr. Bruno Coiffier, IBM, Europe, France

Mr. Coiffier spoke of aircraft designing and analyzing at Avion Marcel Dassault-Breguet Aviation. The design method consists of a sequence of operations using an optimization approach. The Dassault company is the 18th aeronautical company, in size, in the world and has 13,800 employees. The headquarters is near Paris, but the company has operations scattered over many sectors of France.

A system called Conception Assistee Tridimensionelle Inter-Active (CATIA), a geometric mesh programing system, is used in design.

The CATIA is a highly interactive, three-dimensional computer-aided design/computer-aided manufacturing (CAD/CAM) system implemented on IBM computers. The system is packaged in five modules (see *ESN* 37-3:98-99) and, consists of a finite-element core with a database, a solver, and an optimizer. Input to the core consists of information about aeroelasticity, thermics, acoustics, statics, dynamics, and nonlinear mechanics.

A design run for the Mirage 2000 involved 20,000 unknowns and was performed on the IBM 3090 in less than 1 minute. In modeling the HERMES, a structural, finite-element model was used with the CATIA system.

An important materials problem is that of crack propagation, which requires nonlinear three-dimensional analysis. Another important problem is that of mapping the re-entry temperature of the nose of the HERMES.

In the old method of design, a drawing was made to which structural analysis was applied to determine the strength of the marginal components. The final design falls between the negative margin and the positive margin.

The new method requires no drawing, but uses computer output. The input to the computer is the definition of the design variables, which undergo an analysis, using static, finite elements for aeroelasticity, thus producing a definition of optimization of constants as a function of the previous analysis. This, in turn, is input to further sensitive computation, and mathematical optimization, and prediction of an optimum. This is sent back to the analysis using static, finite elements for aeroelasticity and, the process is repeated until convergence in 3 to 4 iterations.

Applying this method to wings and elevons saved 10 percent in weight and improved roll speed efficiency by 25 percent.

The CAD and CATIA programs use the same database. For shape optimization, the design variables are introduced into CATIA. The technique is to be perfected within 2 years.

Concurrent Supercomputing at SERC Daresbury Laboratory, Dr. Martin Guest, Intel Scientific Computers, U.K.

Distributed computing has become more commonplace, and it involves an assortment of systems including: Intel iPSC/2, mini-supercomputers, super workstations, and parallel processing with, for example, the Computing Surface.

Much of the computing work at Daresbury is in quantum chemistry and plasma physics. Our philosophy is based on portability of programs from one system to another and achieving a balance between computing and communicating in our systems.

We have requirements for both fine-grained systems and coarse-grained systems. The work ranges from fine-grained parallelism through vectorization and the use of optimized BLAS.

The Intel iPSC/2 is based on the Intel chip 80386 and the Weitek scalar accelerator. Communications is by direct connect routing.

The software consists of a UNIX operating system and a concurrent workbench system that handles Fortran, C, and uses a vector math library. An important feature of

the system is remote hosting through any UNIX workstation. The central system is hosted by a powerful UNIX processor with well-defined, highly parallel capability. The system has a scalar component plus pre- and post-analysis.

The Intel i860 is a 64-bit RISC (Reduced Instruction Set Computer), with a clock rate of 40 MHz, and a peak performance of 40 Mflops.

In computational chemistry, we do work in molecular, electronic structure, molecular modeling, and molecular dynamics. Table 7 provides a performance comparison for 32-node systems for a problem in computation of matrix elements.

Table 7. Matrix Elements Computation Performance Comparison

System	Units of Time
Convex C210	10,774
iPSC/2	10,427
iPSC/860	2,246

For our work, the strengths of the iPSC/2 include:

- Natural UNIX environment
- Coarse-grained, data-driven system
- Concurrent I/O.

The projected maximum performance of the iPSC/860 is 15 X Convex C210 and greater than the Cray X-MP.

Experiences with a Gigabit/sec Network,
Mr. M. Perdue, Ultra Network Technologies, U.S.

Gigabit/sec networks are a giant leap over what most supercomputer sites have installed and are working now. Most networks today achieve between 500 Kbits/sec and 2 Mbits/sec for a user application. However, within the last year, many Gigabit/sec networks have been installed at supercomputer sites around the world, including Europe. These networks are supporting a variety of applications including high-speed backup of workstation disks, interactive and animated visualization, archive files, distributed processing, and high-speed access to remote systems.

This talk covered experiences with the UltraNet at customer sites. Although most sites are just beginning to integrate the UltraNet into their production environment, data on the effect of such networks are now beginning to emerge. Performance data for memory-to-memory, disk-to-disk, memory-to-disk, and various applications were discussed as collected from multiple sites. Many sites are observing data throughput at a factor of 30 or more beyond what is achievable on installed networks at their sites.

Once the network transport service is no longer the major bottleneck in distributed computing, other interesting bottlenecks emerge. The talk presented actual data and drew some early conclusions on future directions in high-speed networking and network computing based on this experience.

Abstract Machines for Scientific Computation,
Mr. John Taylor, Meiko Scientific, U.K.

The Computing Surface will be adding the Intel chip i860 in order to include hardware, vector processing. The extensive host environment includes VAX, Sun, Computing Surface, IBM PC, and others. There are now more than 300 Computing Surface systems installed.

In an abstract sense, the Computing Surface can be seen as a layered machine architecture:

- Layer 1-Computing Surface and the host environment
- Layer 2-Computing Surface Net (CSN)
- Layer 3-Local and remote service layer
- Layer 4-Configuration of library routines to define the resource requirements
- Layer 5-Compilers and debuggers
- Layer 6-Applications software.

Some of Meiko's plans include adding

- Virtual memory capability
- Specialized process elements for increased flexibility
- Standardization for increased portability
- Provision of paradigms for parallel processing
- Generic communication strategies
- Specification environments
- Behavioral transparency including determinism and fault tolerance.

A Computing Facility for the 1990s, Dr. Bill Buzbee, Director Scientific Computer Division, National Center for Atmospheric Research, U.S.

Over the next 5 years, the pace of change in supercomputing will be unprecedented. The UNIX operating system will dramatically alter the use of supercomputers. Within 5 years, parallel processing will be dominant.

Global warming of the climate via "greenhouse gases" will likely be an international sociological problem in the 1990s. To understand it and to respond to it, should it occur, improved predictive capabilities are needed. The use of computers in the modeling of climate will constitute one means of providing that improvement. The next generation of supercomputers will offer an order of magnitude increase in processing power if multitasking and parallel processing are used. Consequently, we anticipate that climate modelers will make extensive use of multitasking and parallel processing in the 1990s. But an order-of-magnitude increase in computational power has dramatic implications for archival storage and analysis of results; the transition from monoprocessing to parallel processing has significant implications for software development. The National Center for Atmospheric Research is constantly changing and building an infrastructure of resources, such as archival storing, visualizing, and dis-

tributed computing, that will support climate modeling and exemplify supercomputing in the 1990s.

The Cray Y-MP Series of Computer Systems,
Dr. Derek W. Robb, Cray Research Inc., U.S.

The Cray Y-MP is the dominant hardware product of Cray Research, and UNICOS is the dominant software product. Two important advanced projects at Cray are the C90 and the YM/P+.

The following systems have been produced and shipped: Cray 1 (64), Cray 2 (30), Cray X-MP (190), and Cray Y-MP (32).

The Cray Y-MP consists of:

- Symmetric multiple processors with a common memory
- 2, 4, or 8 processors
- Clock speed-6 ns
- Memory capacity can be 16, 22, 64, or 128 million words
- Highly modular system in which 1 CPU is one module, and the system i field upgradable
- Extensive very-large scale integration (VLSI) logic; system uses custom-built 2500 emitter-coupled logic silicon gate arrays
- System is upwardly compatible with Cray X-MP 41 modules in Cray Y-MP.

In parallel processing, the system uses Macrotasking via subroutine calls, microtasking via computer directions, and autotasking in which no program intervention is required.

Network connections are by means of hyperchannels and ultrabuses.

On the spectral model of the European Centre for Medium Range Weather Forecasts (ECMWF), the Cray Y-MP gives a sustained performance of 1.138 Gflops. Other programs which it runs in minutes include: the General Electric jet engine finite element analysis; the Ford automobile engine analysis; the shuttle launch engine for NASA; and the NASA windtunnel computations.

An autobody, analysis computation is run at a speed of 1.7 Gflops. A model of hemisphere insolation is run at 1.26 Gflops, and an ocean warming program at 1.1 Gflops.

The C90 project will have:

- Compatibility with the Cray Y-MP
- 16 CPU shared memory
- 4-ns clock cycle
- Double speed vector/CPU
- Double length vector registers
- Central memory 512 Mword
- Higher performance I/O system
- Customized 10,000 gate array VLSI and integrated circuit technology for logic circuitry.

There will be a C-90 follow-on with more processors, a new memory organization, improved availability using silicon (Si) and GaAs technology, more gates/chip, faster clock, and increased reliability. The performance objectives will include balanced scalar, vector, and I/O performance aimed at a peak performance of more than 100 Gflops.

Desktop Parallel Supercomputers - the Future,
Mr. Adrian Lincoln, Scientific Computers, U.K.

Supercomputers have often been seen as inaccessible machines that are expensive and difficult to use. The trend has been toward smaller machines that may not provide the ultimate peak performance of their elder brothers, but are more accessible.

The development of highly integrated VLSI and their use in building parallel computers makes it possible to produce a very powerful computer that can sit on a desk. Although it is easy to build parallel machines, it is somewhat more difficult to make them easy to program.

Cogent Research has developed a desktop, parallel supercomputer that addresses the issue of programing parallel machines. Using the Linda paradigm, the Cogent Research system embodies parallelism at both the user and operating system level.

This paper reviewed the background to the development of an architecture and topology independent operating system and its software environment. The paper outlined the key features of using the Linda approach as a high-level, programing abstraction and its long term benefits in providing portability of programs. The paper concluded by reviewing the operation and performance of the XTM system developed by Cogent Research.

Supercomputing with the NAG Library,
Mr. J. Du Croz, Numerical Algorithms Group Ltd., U.K.

The NAG library offers users of supercomputers a library of subroutines that save the users the trouble and need for specialized knowledge. The library also cushions users from the inconvenience of changing technology.

Portability of these subroutines is at two levels: at the user interface and in the underlying code. The library has been implemented on 17 supercomputers and minisupercomputers. The subroutines for random number generation and for quadrature have given for some machines a speedup by a factor of 8 or 9 over previous methods. The subroutine for Fast Fourier Transforms allow longer vectors and obtain higher execution speeds.

In the linear algebra subroutines, there is no need to redesign the user interface. The algorithms can be restructured and software can be constructed for a small number of computational kernels. The NAG linear algebra routine ran on a Cray Y-MP at a reasonable fraction of its maximum.

The NEC Supercomputer SX-3 Series, Mr. Tadashi Watanabe, NEC Corp., Japan

The NEC SX-3 supercomputer was developed to meet the growing demands for large, high-speed computations. This series consists of seven models based on the number of processors and the number of vector pipelines installed per processor. The speed of the models range from a 1.4 Gflops uniprocessor entry model to a 22 Gflops four processor top-end model. The presentation covered basic hardware technologies and architecture of the SX-3 series. Table 8 provides NEC SX-3 features.

Table 8. NEC SX-3 Features

- Multiprocessor system with up to four arithmetic processors; extremely powerful
- High-speed, single processor performance of 5.5 Gflops peak achieved by a machine cycle time of 2.9 ns and 16 vector pipelines
- Leading-edge technologies, such as VLSI, with 20,000 gates and 70 picosecond switching speed, and high-density, multi-chip packages
- Super-UX, a UNIX-based operating system, with multiprocessors and -processing functions
- Fortran 77/SX with auto-parallelizing and vectorizing functions, and various tuning and debugging support tools.

IBM Supercomputing Trends and Directions, Dr. Alec Grimison, IBM Data Systems Division, U.S.

One consideration in a supercomputing system is how to keep I/O up with processing speed. Table 9 provides the most critical elements in system strategy for a supercomputer.

Table 9. Supercomputer Critical Elements in System Strategy

- Balance in scalar, vector, and parallel computing
- Balance the computing speed with memory size and I/O speed
- High performance while preserving customer investment
- Use moderate parallelism with a shared tightly coupled global memory
- Use memory hierarchy
- Balance throughput and turnaround needs.

In the 1990s, IBM faces the issue of remaining compatible and competitive. The basic strategy is to continue to enhance the 3090 VF while remaining compatible with installed systems. The systems will have advanced function and increased performance without losing the compatibility.

Should parallelism be maintained at many or all levels including supercomputers, mainframes, mini-supercomputers, and workstations?

There will be enhancement opportunities for specialized facilities such as in the Supercomputer System Initiative (SSI). We intend to use very high-speed system interconnections. The application and system software should present a seamless user interface.

Supercomputer extensions may include a new category of strategic products with emphasis on the commitment to super and a bridge to the future. Tables 10 and 11 provide SSI overview and developmental plan, respectively.

Table 10. SSI Overview

- Up to 64 processors
- High speed I/O
- Large, real memory
- Optimized for solution time
- Performance objective: 100 X Cray 2
- UNIX based operating system
- Support Fortran and C
- Optimized parallelism.

Table 11. SSI Developmental Plan

- To build the biggest and fastest computer possible
- For IBM to have only a minority interest
- To have logic like the 3090 processors
- To provide IBM benefits, including a look at IBM technology from an outside.

The U.K. Universities' Global Atmospheric Modeling Project, Professor B. Hoskins, University of Reading, U.K.

With the arrival of a Cray X-MP/48 at the Rutherford Appleton Laboratory (RAL), a group of nine principal investigators (based in six separate universities and RAL) requested a major research grant from the Natural Environment Research Council. The aim was to develop a hierarchy of numerical models of the atmosphere and to use them as tools to increase our understanding of the global scale climate and chemical environment. To the model already developed at Reading, added versions have been made of the operational weather forecasting model of the ECMWF.

One of the difficulties is that we are dealing with a chaotic system where small changes can have large effects. There is considerable feedback in the association between the atmosphere and the ocean and all the components interact.

The global atmospheric system is driven by radiation which causes convection in the tropics, cyclonic, and

anticyclonic motion in the middle latitudes, and stability in the stratosphere. The global circulation model uses 2500 grid points at 10 levels in the atmosphere. We use 30 to 40 time steps per day in our iterations.

Sea Modeling Using an AMT DAP, Dr. Alan J. Cooper, Hydraulics Research Ltd., U.K.

Civil engineering hydraulics deals with rivers, reservoirs, waves, harbors, estuaries, and marine pollution. The various methods used in our investigations include field investigation, scale physical modeling, and computer modeling.

- The DAP that we use has 4096 elementary processors and uses a Sun as host, including a network of Sun workstations. We use Fortran + for matrix and array operations and for logical masks.
- We work with one-, two-, and three-dimensional estuary models. The model considers turbulent mixing, wind interaction, and mud particles settling.
- We use shallow water equations, and our numerical solution methods include both implicit finite and explicit differences. The latter are used in two-dimensional problems, and the former in three-dimensional problems.

A principal application is cooling water studies which considers recirculation and power station efficiency.

Will Europe Succeed in the Supercomputer Market?

by J.F. Blackburn

Introduction

During the 1980s, the number of classic supercomputers in Europe grew from almost none to about 200 systems installed and working. American manufacturers supplied about 90 percent and the rest by Japanese manufacturers. But the situation is changing, and European manufacturers are beginning to enter this market. At this stage, it appears that the success of European manufacturers will depend on the success of fine-grained parallelism (parallelism at the statement level in supercomputers, as opposed to coarse-grained parallelism executing groups of statements or complete subprograms in parallel). Coarse-grained parallel machines tend to have a relatively small number of processors (typically, up to six) while fine-grained parallel machines may have hundreds or thousands of processors.

The only serious effort in Europe to develop a coarse-grained vector processor system was by the Bull Company in France. The development called ISIS has occupied Bull for most of the 1980s. This is a vector processing pipeline system with a 16-fold interleaved central memory for data and instructions. This common memory is also used by four scalar integer/floating-point processors. The basic technology used by ISIS is Emitter Coupled Logic gate arrays.

The scalar processors are pipelined, 64-bit Reduced Instruction Set Computer processors. Each processor includes an instruction cache, and 256 general purpose registers for 64-bit integers, and floating point values. The scalar processor fetches tasks from the memory and executes them if they are scalar operations. The vector instructions are passed to the vector processors. Since there are four scalar processors, four tasks may be executed at the same time. The 256 general purpose registers are used by an optimizing compiler to reduce the number of accesses to memory. Each scalar processor has its own page translation table.

The vector unit has 8 to 32 processing elements, each of which is internally pipelined and performs 64-bit integer and floating point operations. The processing elements have their own sets of constant registers and vector registers. With a clock frequency of 32 MHz, each processing element has a peak performance of 32 megaflops. A maximum configuration with 32 processing elements has a peak performance of 1 gigaflop.

The main memory is Complementary Metal Oxide Semiconductor (CMOS) Static Random Access Memory with a word length of 64 bits. The memory is organized into four banks, each interleaved 16-fold. Consequently, four words can be accessed in parallel during one clock cycle using a cross-bar switch. So the memory bandwidth is one gigaword per second for each of the two operand streams and the result stream.

The main memory is backed up with a secondary memory of 512 megabytes of Dynamic RAM (DRAM). The interconnection of both memories is capable of transmitting four words per clock cycle. The system is completed by a hyperchannel interconnection with one or more front-end machines to handle input/output and to perform program compiling and job preparation. The user software interface is UNIX V compatible and pro-

vides a job control language, file handling system, function library, compiler for a vector-extended Fortran, and vectorizer for standard Fortran.

The first prototype for this supercomputer became operational in 1988 but appears unlikely to be marketed. Thus, Europe's future success in the manufacture and marketing of supercomputers is likely to depend on the massively parallel fine-grained system, probably built from the transputer, developed by Inmos of Bristol (see *ESN* 39-9:443, *ESN* 40-4:142, *ESN* 40-9:306-308, and *ESNIB* 88-01:29-31).

The Transputer

Although there are several versions of the transputer, this discussion will refer to the T800, the most widely used version. More than 100,000 were sold in 1989, and it has been used as the microprocessor in over 500 computing systems sold over the last 2 years. However, very few of these would qualify as supercomputers because most have a relatively small number of processors/systems. They can, however, be very easily expanded to supercomputers by adding more processors.

The T800 is a 32-bit CMOS microcomputer with a 64-bit floating point unit and graphics support. It has 4K bytes of onchip RAM for high-speed processing, a configurable memory interface, and four standard INMOS communication links. The instruction set achieves efficient implementation of high-level languages and provides direct support for the Occam model of concurrency when using either a single transputer or a network of transputers (see *ESN* 40-9:306-308). Procedure calls, process switching, and typical interrupt latency are submicrosecond.

The processor speed can be pin-selected in stages from 17.5 MHz up to the maximum allowed for the part. A device running at 30 MHz achieves an instruction throughput of 15 MIPs. The T800 provides high-performance arithmetic and floating point operations. The 64-bit floating-point unit provides single and double precision. This unit is able to perform floating-point operations concurrently with the processor at a rate of 1.5 megaflops at a processor speed of 20 MHz and 2.25 megaflops at 30 MHz.

Graphics support is provided by microcoded block-move instructions which operate at memory speed. The two-dimensional block-move instructions provide for contiguous block moves as well as block copying of either nonzero bytes of data only or zero bytes only. Block-move instructions can be used to provide graphics operations such as text manipulating, windowing, panning, scrolling, and screen updating.

Cycle redundancy checking instructions are available for use, on arbitrary length serial data streams, to provide error detection where data integrity is critical. Another feature of the T800 that is useful for pattern recognition is the facility to count bits set in a word.

The T800 can directly access a linear access space of 4 gigabytes. The 12-bit wide memory interface uses multiplexed data and address lines and provides a data rate of up to 4 bytes every 100 nanoseconds (40 Mbytes/sec) for a 30-MHz device. A configurable memory controller provides all timing, control, and memory refresh signals for a wide variety of mixed memory systems. System services include processor reset and facilities for error analysis. Error signals may be daisy-chained in multi-transputer systems.

The standard INMOS communications links allow networks of transputer family products to be constructed by direct point-to-point connections, with no external logic. The T800 links support the standard operation speed of 10 megabits/sec, but it can also operate at 5 or 20 Mbits/sec. Each link can transfer date bidirectionally at up to 2.35 Mbytes/sec. The transputer is designed to implement the Occam language, but it also efficiently supports other languages including C, Pascal, and Fortran.

The T800 has been used as the microprocessor in several parallel computers, most notably the Computing Surface manufactured by Meiko in the U.K., the SN1000 manufactured by Parsis in the U.K., and the T-Node manufactured by Telmat in France. These systems will be discussed in the following paragraphs.

The Computing Surface

The manufacturer of the Computing Surface is Meiko of Bristol, U.K., a company founded a few years ago by seven employees of Inmos. By the end of 1989, Inmos had sold well over 200 such systems after only beginning sales in mid-1986.

The Meiko Computing Surface is composed of modular subsystems that permit optimization of *compute*, *store*, and *input/output* to particular classes of application, together with straightforward software and tools essential for programing this class of machine.

Various approaches to using the Computing Surface are possible. Since every transputer is a significant computer by itself, the Computing Surface can be treated as a multitask environment, with a separate independent task per computing element. An example is a numerically intensive simulation. Often many simulations have to be performed on the same dataset with different starting or operating conditions. The set of simulations is the overall task; however, conventionally, the performance of any individual simulation is measured and optimized, performing each one of the set of simulations simultaneously with the others with no interaction between them, and leads to a linear decrease in elapsed time.

The other extreme is the distributed implementation, involving a fresh look at the problem or tackling a problem that was previously looked upon as infeasible with conventional computers.

A Computing Surface is formed by networking many computing elements in an application-specific topology. Each computing element is a self-sufficient, independent, hardware process, with processor, memory, and high-speed, point-to-point communications channels.

In the Computing Surface, users impart their own concepts to the machine, without the constraint of arbitrary choices by the developer. Thus, configurations can be optimized for the applications.

The support infrastructure can detect hardware or run-time errors in any individual computing element and perform an immediate analysis. A problem is pinpointed by positioning the program source editor at the offending line of code and naming the process instance in which it has occurred. Application diagnostic messages are assured of a guaranteed route to the console or host computer, by using a communications structure which is independent of and orthogonal to the configurable network.

Software is used to specify the machine as well as the application program. Occam specifies connections, communications, and computations in one consistent formally based notation. The transputer was designed to implement the Occam model and execute Occam code. The Computing Surface was designed to deliver transputers and to support application development.

The Computing Surface can also be programed in Fortran, C, Pascal, and other languages. Executing such programs requires an Occam harness to handle communication with other processors, which may be executing copies of the same program.

The M40 Computing Surface module has a peak performance of 1.1 billion instructions per second, with 42 megabytes of concurrently accessed RAM. The effective bandwidth of the store is 24 gigabytes per second, with a peak bandwidth of 9 gigabytes per second to 300 kilobytes of closely coupled static RAM. An arbitrary number of modules can be used together.

The Supernode

The ESPRIT Project 1085 resulted in the development of the Reconfigurable Transputer Processor (RTP) Supernode Machine. The basic design is a modular, hierarchical architecture based on reconfigurable nodes of transputers. Very large-scale integration (VLSI) switches (designed at Southampton University) under transputer control determine the topology of the network within and between nodes. Reconfiguration can be done during program execution under the control of the program. Hence, the configuration can be matched to the bandwidth requirements of the application.

A supernode consists of 16 worker transputers, each of which is a T800. The four links of each worker transputer are connected to a 72x72 VLSI switch that is controlled by a further transputer with its links connected to the switch. Each T800 has 256K bytes of external memory. The node has an additional transputer with 16M bytes of external memory for storing and distributing data and code. A Winchester disk, controlled by an M212 transputer, can be included in the node. An internode switch is used to implement a three-stage network for reconfiguration between nodes.

A control bus enables any transputer to communicate with the control transputer independently of the links. This is used for synchronizing and debugging programs. The RTP supports static, quasi-static, and dynamic operation of the switched system.

The estimated peak performance of a supernode is in excess of 32 megaflops per second. An arbitrary number of supernodes can be used in a system. A multinode computer with 1024 transputers has an accumulated megaflop rate of 2 gigaflops.

The RTP is sold by Parsis in the U.K. as the SN1000 and by Telmat in France as the T-Node; together, the two companies have sold more than 200 systems.

Suprenum

Suprenum has been extensively discussed (see *ESN* 41-2:71-75 and *ESNIB* 89-08:80-85). Briefly the Suprenum development began in mid-1986, funded partially by the Federal Republic of Germany (FRG) government and by four participating FRG companies. This development consists of bus-connected independent clusters, each of which contains 16 working nodes and each with its own local memory. Communication between nodes in a cluster and between clusters is by message passing. On each node, the Process Execution and Communication Environment (PEACE) operating system is in use. The system has a front-end processor, using the UNIX operating system. A Suprenum system with 16 clusters is expected to have a peak performance of 5 gigaflops; i.e., with 256 working nodes.

A Suprenum node is a complete single board vector processor running its own operating system--PEACE--and communicating with other nodes. A node consists of:

- Node central processing unit (Motorola MC68020, 20 MHz) with paged memory management (Motorola MC 68851) and scalar arithmetic processor (MC 68882)
- 8 Mbytes of node memory (DRAM, 35 ns static column access time)
- Pipeline vector processor (Weitek WTL 2264/2265 chip set) in connection with a microcoded controller

accommodated in an application-specific integrated circuit
- Dynamic memory address generator for block transfer of data structure objects
- Communication coprocessor for internode communication.

A 32-node system (two complete clusters) was demonstrated at the Hannover Fair in April 1989, and a 256-node system (16 full clusters) was completed in late 1989.

The GENESIS Project

GENESIS is Project Number 2447 in the ESPRIT II program. This architecture is a concept for a family of supercomputers meeting the following goals:

- Highest possible performance, obtained through a highly parallel multiple instruction multiple data stream/single instruction multiple data stream architecture with distributed memory
- Optimum cost effective, achieved by exploiting the latest advances of VLSI technology
- Wide-range system with scalability and extendability
- Long product life, ensured by defining the abstract machine independently of the current state of the technology
- Highly reliable, ensured by an optimal degree of fault tolerance
- The exploitation of highly parallel architecture provisioned by a programing environment.

The partners in the development of GENESIS are the Suprenum Consortium (FRG), Bull (France), Inmos (U.K.), Siemens (FRG), and others. The expectation for GENESIS is to have a peak performance of 100 gigaflops, with up to 1024 processor nodes interconnected by a two-stage hierarchy of crossbar networks. First level clusters will include 32 interconnected processor nodes. The next level up will include 32 interconnected clusters for a total of 1024 processor nodes.

A processor node will consist of a central processor (integer unit), a vector processor with vector register memory, communication processor, and main memory. The central processor will be a pipelined scalar processor, executing 50-60 millions of instructions per second (MIP), and two independent floating point units, performing up to 60 megaflops each. The vector processor will originally have a peak performance of 120 megaflops (double precision) to be increased as technology permits to 200 megaflops.

The separate communication processor will use new concepts to reduce the startup time to a nearly negligible amount. The node memory will have a capacity of at least 32 Mbytes and will be 256-bits wide.

Since GENESIS is now in the definition phase, it is not clear whether it will be transputer-based (preferred by Inmos) or Motorola microprocessor-based (probably preferred by Suprenum). There will be interest on the part of officials and other participants in the ESPRIT program in using the transputer since GENESIS is being billed as "the first truly European supercomputer," and the transputer is a European development.

Conclusions

Inmos has developed a successful microprocessor in the transputer. The microprocessor is selling well (100,000 in 1989) and is being used in a great many products under development and in several computing systems, potentially capable of becoming supercomputers already on the market and installed. The combined product sales of transputer based products by Meiko, Parsis, Telmat, and Parsytec number more than 500 systems. Some of these systems can be classified as supercomputers; e.g., the 400 processor system at Edinburgh University. There is a strong probability that the transputer will be the microprocessor used in the GENESIS system.

European planners and manufacturers are basing their operations on the assumption that the fine-grained, massively parallel supercomputer will prove to be more cost effective than the present-day large, coarse-grained vector systems. They also believe that the programing problems that have to be solved to effectively use such systems can be solved. If they are right on both of these assumptions, then European manufacturers will have an important role to play in supplying the supercomputers of the future. Furthermore, systems of various sizes, based on the transputer, can be used effectively as intelligent workstations and as mini-supercomputers. The latter category is a very rapidly growing segment of the computer market.

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ELECTRONICS

Nondestructive Testing Conference

by Irving Kaufman, College of Engineering and Applied Sciences, Department of Electrical Engineering and Center for Solid State Electronics Research, Arizona State University, Tempe, Arizona.

Introduction

A routine physical examination, the test flight of an airplane, and the measurement of noise figure of an amplifier are all procedures that could be called Nondestructive Testing (NDT) or Nondestructive Evaluation (NDE). However, accepted practice is to use these terms to refer principally to the detection of defects in mechanical systems, or in materials used in these systems.

While recent spectacular accidents involving airplanes have emphasized the need for inspection to the general public, engineers and managers have recognized the benefits of such inspection; i.e., NDT, for some time. For example, periodic inspection of components in electric generating plants during the past 15 years has reduced expensive failures in these plants considerably compared to before these NDT procedures became the rule.

To exchange ideas on NDT techniques on a worldwide basis, a periodic World Conference on NDT (Conference) now is held every 3 or 4 years with a venue that moves from continent to continent. The 1985 meeting was held in the U.S.; in 1989, the 12th Conference was held in the Netherlands. The 13th is scheduled for Sao Paolo, Brazil, the 14th for India. This report provides information about the April 23-28, 1989, meeting.

Organized by the international organization International Congress on Nondestructive Testing (ICNDT) and hosted by the Dutch Quality Surveillance and Nondestructive Testing Society, (KNIT) the Conference took place at the large conference center, RAI, in Amsterdam. There were approximately 1,300 participants from over 60 countries, including Luxembourg and Barbados, the U.S., U.S.S.R., and China. Conference Chairman and ICNDT President (1985-1989) was G.M. van Dijk, KEMA, N.V., Arnhem, the Netherlands. J. Boogard, DSM Research bv, Geleen, presided over the Scientific Committee and the 50 reviewers of technical papers, among whom were representatives of such well-known Dutch organizations as Shell Research, Fokker Aircraft, KLM, and TNO Institute of Applied Physics.

Although scientifically based, an NDT conference differs from the majority of others reported in the *ESNIB* in that the interest is not only on the development of new techniques, but also on immediate application. To this end, among the participants were representatives from the steel, chemical, and manufacturing and servicing industries, as well as various organizations specializing in NDT. Among the latter were the National Nondestructive Testing Centre, Harwell, U.K.; the Fraunhofer Institut füer Zerstöerungsfreie Pruefverfahren, Saarbruecken, Federal Republic of Germany (FRG); the NDE Institute of Canada; the Centro Sviluppo Materiali s.p.A., Rome, Italy; and the Danish Welding Institute, Brondby, Denmark. In addition, since NDT depends heavily on the use of proper instruments, a very important part of the Conference was a giant exhibit, in which various vendors and service organizations displayed their products and talents.

The NDT can involve product inspection during manufacturing, determining material structure or content, and discovering possible defects. In many cases, the latter means identifying material degradation or locating faults such as cracks that under continuous stress could lead to equipment failure. Crack detection has therefore become a very important aspect of NDT.

Progress was reported or discussed in 42 technical oral sessions in these various aspects of NDT, methods of educating, training, qualifying, and certifying personnel who are to execute NDT procedures, develop standards, assess the reliability of NDT, and NDT in developing countries. If these sessions could not keep the participant sufficiently busy, there were concurrent poster sessions, with new posters every day, plus the multinational show in the giant exhibit hall.

To emphasize to the participants the Conference location, while at the same time staying with the NDT theme, the formal sessions opened with a presentation that related NDT to the work of Rembrandt, Amsterdam's famous citizen. Thanks to an NDT procedure, we now know, 200 years later, what went through the mind of

Rembrandt while he was creating some of his most famous paintings. Mr. Guido Van de Voorde, Royal Institute of Art Patrimony, Brussels, using x-ray analysis, had found that in creating the famous painting, "The Phantoms of the Draper's Guild," the artist experimented with various sketches before he settled on the most effective positions and poses of the officials depicted. For this NDT detective work and other NDT-in-art accomplishments, Mr. Van de Voorde was given a special award during the closing ceremony of the Conference.

Plenary Sessions

Several speakers discussed their specialties. Names, summaries, and in some cases, comments, follow:

Dr. K. Goebbels, Tiede Risspruefanlagen, D 7087 Essingen, FRG, apparently a "surface NDT" person, justified his approach to NDT with the theme that since the surface of a body is usually subjected to the highest stress, it is most vulnerable and should have the highest NDT priority. He then reviewed various methods of NDT:

- Liquid Penetrant Testing (LPT) and Magnetic Particle Inspection (MPI). Both methods depend on the use of fluorescent dye. When such liquid dye is sprayed on a surface, it seeps into the cracks and thereby highlights when illuminated with ultraviolet light. In MPI, magnetic particles covered with the dye collect at cracks in magnetized material. Dr. Goebbels felt these to be the most sensitive methods for inspecting components in a production line, least disturbed by geometry, surface roughness, and material microstructure. They are used annually in the inspection of approximately 10 billion manufactured safety-related components. (In a contributed paper, he later discussed closed-loop, automated MPI techniques that reliably detect cracks 1.5 mm or longer on continuously produced parts, with part test line speeds up to 1.5 m/s.)
- Radiation Methods (x rays, neutrons, isotope sources). Past limitations of finding defects only for depths greater than 1 percent of wall thickness and with orientation deviating less than $\pm 15^{o}$ from the radiation direction have been overcome by Computer Tomography, Compton Backscattering, and x-ray diffraction microscopy. Defect orientations are no longer a restriction. X-ray sources of spot sizes as small as a few μm are now state of the art. Modeling of radiography and fully automated system are being developed. A drawback: Radiography does not provide the data necessary for fracture mechanics evaluation of a structure.
- Eddy Current (EC) and Ultrasonics (UT). EC and UT can do crack sizing. For efficient crack detection, they require a depth-to-surface roughness ratio of at least 3 and a defect-to-random-microstructure ratio of 2. They can be fully automated. Given the proper financial support, EC-imaging and detection of pre-stages of cracking (for conducting materials) should be able to reach the effectiveness of ultrasonic testing, the present leader in these areas.
- Scanning Acoustic, Scanning Laser Acoustic, Photoacoustic, and Photothermal Microscopy (SAM, LAM, PAM, PthM). Are capable of μm size resolution, with applications of NDT to electronic devices. The PAM and PthM have the advantage of being contactless.
- Acoustic Emission (AE). Noise emitted while cracks are formed or grow as material is stressed can now detect and locate crack areas down to 1 mm^2. Cracks already present are also detectable during cyclic compressive stressing or thermal shock.
- Thermography. In thermography, a surface is exposed to transient heating. A map of the surface temperature distribution, obtained by sensing the black-body, or thermal radiation concurrently with or immediately following the heating, indicates the location of cracks.

Dr. Goebbels pointed out that the need for NDT is shifting significantly from volume and large defects to surface defects, to smaller defects, and to materials characterization. This shift is because of the capability of increasingly producing materials of greater homogeneity or specifically designed inhomogeneous material. (For the sake of completeness: there are additional methods of surface NDT. I have mentioned two of these, Optical Scanning [OS] and Radiometric Emissivity Imaging [REI] later in this text.)

Professor Dr.-Ing, E. Mundry, in collaboration with D. Schnitzger, BAM, Berlin, FRG, discussed recent and expected future developments of NDT technology and applications:

- For fiber reinforced composites: ultrasonics, vibration and sound, thermal methods, x rays, optics, and liquid penetrants.
- For ceramics: high-frequency ultrasonics; an ultrasonic microscope; for surface defects--thermal waves. He predicted development of analyses using vibration and micro-x-ray-CT scanning.
- "There is a growing need for NDT in Civil Engineering." Example: Find faults in coupling elements of bridge structures.
- Expansion of thermography work.
- A relatively new development: NDT via Barkhausen Noise (BN). When some ferromagnetic materials are cycled through their hysteresis loops, the flux density changes in small, discrete increments. A

probe detects these small, discrete changes as a noise, the BN.

- Ever-expanding use of computer technology. Examples: computerized tomography; image processing; automatic defect recognition, classification, archival defect storage.
- Ultrasonic inspection to be increased by use of high temperature probes, more extensive use of electromagnetic transducers, and excitation by lasers and noncontacting sensing.
- An increase in the use of thermal waves, shadow Moiré techniques, photoacoustics, nuclear magnetic resonance, vibrothermography, thermoelasticity, positron annihilation, neutron diffraction, and microwaves.

A.J. Berkhout, Delft University of Technology, Laboratory of Seismics and Acoustics, Delft, the Netherlands, an expert on seismic waves, in a mathematical treatment entitled, "A Unified Approach to Ultrasonic Imaging," discussed the inversion of acoustic echoes; i.e., the extraction of defect information. His procedures would apply to any frequency range, from seismic waves (10 Hz) to the waves used for material inspection (up to 19^9 Hz).

Dr. Ir. E.J. Van de Kraats, Koniklije/Shell Exploratie en Produktie Laboratorium, 2280 AB Rijkswijk, the Netherlands, discussed "Knowledge-Based Systems (KBS)," based on Shell's experience with 125 KBSs in operation or under development. Examples: (1) Program for assessing the remaining strength after an offshore rig has been damaged. (2) Interpreting and producing reports on the geochemical analysis of all oil samples sent to the laboratory.

The KBSs emulate human expertise but relieve human experts from routine work while making their expertise available by user-friendly computer programs. His rules for successful KBSs:

- Subject matter must be well-established
- There must be a demand for the KBS being constructed
- User must realize that individuals become dependent on the KBS and can therefore spend their time more fruitfully
- Potential users must be convinced about the system.

In later sessions, S. Segalini and M. Putignani, IRSID, 78105 St. Germain-en-Laye, France; and P. Kleine and B. Backelandt, SOLLAC MARDYCK, 59760 Grande-Synthe, France, described detection of deleterious coarse-grain material in rolls of steel on a pickling line. V.L. Vengrinovitch, V.N. Bus'ko, and S.D. Legotin, Institute of Applied Physics, Byelorussian Academy of Sciences, Minsk, U.S.S.R., discussed development of BN analyzers for finding ferrite-phase content of steels, thickness gauging, and crack location in nonmagnetic coating on a ferromagnetic base. W.A. Theiner, Fraunhofer-Institut für Zerstoerungsfreie Pruefverfahren, Saarbruecken, FRG, and V. Hauk, Rheinisch-WestFaelische Technische Hochschule Aachen, Aachen, FRG, used BN to characterize surface states in shot-peened steel sheets.

Technical Sessions

There were more than 500 additional papers. A sampling of papers dealing with NDT techniques follows:

Radiography. Compton Backscattering by W. Roye, Philips GMbH, Industrial X-ray Supply Centre, Hamburg, FRG. "Comscan" is noncontacting, therefore requires no special surface finish. Measurements can be carried out from one side of a specimen only. Provides information on depth of a fault.

Dynamic Neutron and Gamma Ray Radiography by M. Balasko and E. Svab, Central Research Institute for Physics, H-1525 Budapest, Hungary; and A. Burtscher, Austrian Research Centre Seibersdorf, A-2444 Seibersdorf, Austria. Neutrons penetrate almost all metals of technical interest but are highly attenuated by materials containing hydrogen. Gamma rays are absorbed by the heavy elements but easily penetrate materials containing hydrogen. Balasko et al., have made use of neutrons to visualize flow, boiling, and condensation in metal tubes while at the same time imaging the inner metal parts of the containers with gamma rays. The source: the 8-Mw reactor at Seibersdorf. Among the applications: examination of heat pipes, absorption and compression type refrigerators, oil pump systems, hydraulic robot systems.

Density Resolution Estimation for Gamma Ray Tomography by T. Kanamori, S. Kamata, Energy Research Laboratory, Hitachi, Ltd., Ibaraki 316, Japan; and S. Ito, Hitachi Works, Ibaraki 317, Japan.

Gamma ray Computed Tomography (CT) can be used to measure densities of objects. But while for calculations of density resolution for x-ray CTs passing through low-density material (e.g., the human body), the average number of photons can be used, an effective photon count that takes noise propagation into account must be used for gamma ray CT of high-density materials.

Digital Tomography by K.C. Tam, General Electric Co., Schenectady, New York. In digital tomography, or laminography, techniques of limited-angle reconstruction can be applied to remove the blurring on tomographic planes, thereby significantly improving the image quality in the inspection of closely spaced layers, such as those in multilayer printed circuit boards.

X-ray Film. Several papers dealt with stability, resolution, and signal-to-noise ratio of radiographic film. In addition, J.C. Domanus, Riso National Laboratory, Roskilde, Denmark, reported on results of precise neutron radiography dimensional measurements of a fuel pin, carried out by the Euratam Neutron Radiography Group

in six different countries. (High accuracy of dimensional measurements is desired when controlling the behavior of irradiated nuclear reactor fuel.) The results reported covered the type of film, radial vs. axial measurements, and the instruments that performed the measurements.

Ultrasonics. Among papers dealing with ultrasonics were the following:

Automatic Scanning by H.E. Gundtoft, K.K. Borum, and P. Toft, Riso National Laboratory, Denmark. Robotic systems can perform automatic thickness measurements on a doubly curved surface or are in use for automatic inspection of tubes for dimensions and defects. The accuracy in dimensional sensing and the associated computer processing was dramatically demonstrated by an ultrasonically obtained image of the front face of a coin.

Elastic Wave Scattering by K.J. Langenberg, K. Mayer, and T. Kreutter, University of Kassel, FRG; V. Schmitz, Fraunhofer Institute for Nondestructive Testing, Saarbruecken, FRG. In this mathematical paper, scattering by defects in solids was treated in terms of timely separated pressure and shear wavefronts, each of which is approximately characterized by a scalar potential. If the defect can be considered as a weakly scattering inclusion or a strongly scattering crack or void, formulation of the inverse scattering problem then yields a general solution via the backpropagation ansatz. Holography, ALOK, SAFT, Echo Tomography, and other algorithms for computed imaging are special solutions within this generalized diffraction tomography framework. The investigators also reported on alternatives, such as Fourier-Transform SAFT for either planar or cylindrical surfaces.

Crack Monitoring by S. Terpstra and J.P. Pasma, Shell Research, B.V., Amsterdam; and G.P.C. van Woerkom, Shell Nederland Raffinaderij, Rotterdam. Two methods of monitoring the growth of defects of a weld in a cylindrical vessel 55m (!) high were compared: Time of Flight Diffraction (TOFD) and Flaw Tip Reflection. The TOFD method was superior and sufficiently reproducible. For the particular weld geometry, a standard deviation of 0.75 mm in defect location existed.

Transducers by A. Lhemery and D. De Vadder, Laboratoire Materiaux URA 248 CNRS, Ecole Central de Paris, France. Based on conclusions from their theoretical results, the authors proposed an experimental method for characterizing the vibration amplitude distributions of plane or slightly focused disk transducers.

Sound Fields by K. Harumi, Tokyo University of Information Sciences; K. Date, Miyagi National College of Technology; M. Uchida, College of Industrial Technology, Nihon University; and H. Shimada, Akita National College of Technology, Japan. Images of sound fields that were calculated to exist when an ultrasonic wave in a solid intercepts a hole or crack were presented in several papers. They were compared with photographs obtained by photoelastic visualization of fields from such faults in glass. The agreement was remarkable.

Ultrasonic Testing of Shallow Subsurface Regions by H.A. Crostak, K.J. Pohl, and F.D. Schroeder, University of Dortmund, Fachgebiet Qualitaetskontrolle, FRG. Ultrasonic testing reveals faults within the bulk of a specimen, not immediately below the surface. A new technique was described by which faults in subsurface regions can now be located. The surface is illuminated with two strong laser pulses and the surface is recorded holographically after each pulse. Subsurface faults are revealed as disturbances in the otherwise homogeneous interference fringes of the superimposed holograms.

Grain Size Determination in Thin Metal Sheets by M. Paul, H. Peukert, and W. Arnold, Fraunhofer-Institut füer Zerstöerungsfreie Pruefverfahren, Saarbruecken, FRG. A Q-switched laser pulse generates broadband ultrasonic pulses at the front surface of a metal sheet. Grain sizes in the sheet are determined by analyzing the spectral change in subsequent back surface echoes and by using the Rayleigh scattering approximation.

Electromagnetic Testing. Following a sampling of papers that involved electromagnetic effects.

Remote Field Eddy Current Testing by B. David, Commissariat Energie Atomique; J. Slazak, R. Legai, Intercontrole; and N. Burais, Ecole Centrale de Lyon, France. An eddy current transmission method was investigated in which energy from one coil inside a ferromagnetic tube was transmitted to another one, also inside. They found that this method allowed them to detect corrosion as well as pitting. Some of these faults were not detectable by ordinary eddy current techniques. Maximum sensitivity was achieved with 100-Hz signals; other tests found sensitivity to be maximum at a frequency proportional to $(\text{tube thickness})^{5/3}$.

Magnetic Leakage Flux Testing by I. Uetake, H. Ito, and T. Saito, National Research Institute for Metals, Tokyo. Measurement of leakage flux is used in the automatic detection of surface defects in steel products. Until now, changes in separation between sensor and test piece, as well as the oblique angle of a surface defect, have caused uncertainties in determining defect size. Uetake et al., described a method of solving this problem with a two-element Hall sensor and a measurement procedure involving the slope of signal versus lift-off distance curves.

Inspection of Aluminum Aircraft Structures by G. Tober, T. Meier, and C. Steinberg, Messerschmidt-Boelkow-Blohm GmbH, FRG. Extensive work testing the effectiveness of the eddy current method for detecting fatigue cracks in multilayer aluminum structures led to the conclusion that crack detection based on eddy current measurements taken from the outside of an airplane should be used. Cracks at least 24-mm long that propagated through the entire sheet thickness could be de-

tected with 95 percent probability. (Unfortunately, not with 100 percent.) The general conclusion was that if eddy current measurements indicated defects, the findings should be verified radiographically before extensive repairs are undertaken.

Barkhausen Noise. Discussed in an earlier section of this report.

Noncontacting Mechanical Stress Sensor by H. Yamada, M. Kobayashi, Shinshu University, Nagana; S. Kishimoto, M. Ito, Hitachi Electronics Engineering Co., Tokyo; and H. Wakiwaka, Ono Sokki Co., Tokyo, Japan. When ferromagnetic materials are stressed mechanically, they change their magnetic anisotropy. Investigators found that the voltage developed by a sensing coil when a small 400-Hz current was driven through another coil adjacent to the material had a nearly linear relationship to an applied mechanical stress.

Magnetic Particle and Penetrant Testing. Somewhat to my surprise, a session was devoted to these visual methods of surface crack detection. Items discussed were physical properties, stability, specification compliance, cost effectiveness, process specifications, certification, and environmental and safety considerations.

Acoustic Emission. Among the 50 papers dealing with AE were:

A Review by M. Arrington, Speedtronics Ltd., Somersham Huntingdon, Cambs., U.K. The AE has found uses in: (1) nuclear industry with its use of pressurized components; (2) petrochemical industry--structural monitoring, with offshore monitoring as the most demanding task; (3) aerospace industry--routine ground monitoring as well as in-flight tests; (4) electronics industry--detecting foreign bodies in IC packaging, monitoring thermal compression bonding, detecting delamination in ceramic capacitors; (5) civil engineering--detecting faults in bridges and dams.

AE Intelligent Systems by M.N. Bassim and W. Pedryz, University of Manitoba, Canada. An intelligent system uses principles of pattern recognition for identifying trends in the acoustic signals and detecting the extent of damage. The system deals with the dynamic character of pattern formation and continuous labeling of classes referring to particular characteristics of the structure tested; e.g., stress.

AE Monitoring of Thermal Spray Coating by P. Boehm, H.A. Crostak, M. Dvorak, and H.D. Steffens, University of Dortmund, FRG. In thermal spray coating, metal wires are melted by an electric arc. The molten particles are blown onto the substrate by a high-velocity gas. As the particles hit, they generate acoustic waves. Boehm et al., are attempting to correlate the detected acoustical wave signals with the quality of the deposited film.

AE Source Location for Composite Materials by A. Bouheraqua, Avions Marcel Dassault Laboratoire Structures, Velizy, France. Because of the anisotropy of composite materials and the complex structure of aircraft, triangulation methods for locating the sources of AE signals are not feasible. To overcome this difficulty, M. Bouheraqua attaches four sensors to the structure, which is then acoustically stimulated at various points. By processing amplitudes and times at which the signals are received by these sensors, the system *learns* the locations or origin of the signals.

Two-Dimensional Transducers by J.J. Zhang and D. Xiang, Tsinghua University, Beijing, China. A two-dimensional acoustic transducer composed of a transverse wave plate and a longitudinal wave disk, with one placed on top of the other, have been used to locate the direction of arrival of AE signals.

Thermographic Methods. Following are two papers presented in this area:

Optical and IR Techniques by I. Kaufman, Arizona State University, Tempe. Using differential detection minimizes the effect of surface discolorations in the thermographic methods Photothermal Radiometric Imaging (PRI) and Radiometric Emissivity Imaging (REI). The PRI, which is limited to *off-line* testing, can detect cracks just below the surface, as well as surface cracks. The REI and the OS, while detecting only surface cracks, have been used to map cracks on rapidly rotating surfaces.

Internal Temperature Perturbation Techniques by X. Maldague and D. Poussart, Université Laval, Quebec, Canada; J.C. Krapez and P. Ceilo, National Research Council Canada, Boucherville, Quebec. Thermographic inspection of structures undergoing sudden changes in uniformly applied heat was used to reveal internal structure, thereby revealing wall thickness loss.

Thermography of Composite Materials by P. Delouard, LEMTA, INPL, Nancy; Y-J Marin, I. Avenas-Payan, and H. Tretout, Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France. The applicability and reliability of IR thermography for inspecting composite materials in a production line by use of line heating, line scanning, and real time image processing has been demonstrated. Additional efforts will require increasing detector sensitivity and heating energy density, and developing additional software.

Other Techniques. Other noteworthy presentations were:

Hardness Testing by V.A. Rudnitsky and I.I. Nedbalsky, Institute of Applied Physics, Academy of Sciences of the Byelorussian SSR, Minsk. A method of hardness testing was proposed that is more convenient than the standard discontinuous method of measuring indentor motions before and after impact. The method consists of measuring the time interval between successive bounces of an indentor executing self-excited oscillatory motions while scanning a surface. This technique also possibly

could be applied to flaw detection in bonded or soldered components.

Hardness Testing by R.K. Penny, University of Capetown, Republic of South Africa. In a related technique, a tester has been designed that determines hardness by measuring the height of rebound of a spherical indenter.

NDT in Art by M. Marabelli, Istituto Centrale del Restauro, Rome; and C. Parisi, ALITALIA, Rome, Italy. Since diagnostics and conservation of works of art is important to Italy, two conferences devoted to these subjects were held during the last 6 years. I was amazed to learn of the many techniques that are employed. Among these are accelerator mass spectrometry, x-ray fluorescence, x-ray scattering techniques, Fourier transform infrared spectrometry, a neutron radiative capture method, moisture determination by dc conductivity or microwave attenuation measurements, acoustic vibration techniques, x-ray microanalysis (SEM + EDS), neutron activation techniques, thermographic surveys, x-ray, UV, and IR reflectography, ultrasonic pulse transmission, holographic interferometry, and image processing techniques.

Stress and Vibration Analysis by D.J. Berry and G.M. Everett, Ometron Limited, London. A body that is deformed elastically under adiabatic conditions experiences a rise in temperature, of magnitude proportional to the change in the stress. The effect is known as thermoelasticity. Berry and Everett reported on the development of SPATE, an instrument that senses temperature changes radiometrically and is thereby a noncontacting stress analyzer. They have also extended the use of SPATE to vibration analysis with minute displacements by attachment of a Michelson-type of inter-ferometer system.

Strain Measurement by Digital Speckle Interferometry by A.A.M. Maas and H.A. Vrooman, Delft University of Technology, the Netherlands. This paper dealt with DSI, a nondestructive technique for measuring in-plane strain components of a deformed object. The technique, combined with signal processing, resulted in the most interesting strain maps.

Vibrational Analysis. Several papers dealt with fault detection by analysis of the vibrational spectrum of a system. Among these, J. Runkel and D. Stegeman, University of Hannover, FRG, discussed nondestructive condition monitoring of nuclear power plants. Vibrating structures include not only ordinary machinery, but pendular motions and shell-mode vibration of the reactor pressure vessel, the core barrel, and the thermal shield. While actual particle excursions may be only a few microns, changes in the auto-power spectral density of the velocities of these small excursions may be an indication of possible trouble. The authors recommended that a vibrational survey be on the schedule of routine NDT of every nuclear powerplants.

NDT with Pulsed Lasers by G. Canella, L. Pedicelli, M. Taddei, Centro Sviluppo Materiali S.P.A., Rome, Italy. Laboratory tests carried out to evaluate applicability of fault detection by monitoring signals generated when a pulsed laser beam strikes a surface indicated that of the various techniques of monitoring generated signals, only detecting acoustic pulses could find industrial application.

Sensors, Equipment, Computers, Applications, Reliability of NDT, and Training and Standards

In the preceding material, I have concentrated on results of work that dealt principally with techniques of NDT, since I felt that a treatment of techniques would probably be interesting to the average person. Actually, as the title of this section indicates, much other material was also covered at the conference.

Conclusion

Abstracts and summaries for most of the papers presented were published in "Proceedings of the 12th World Conference on Non-Destructive Testing, the Netherlands, April 23-28, 1989." Edited by J. Boogard and G.M. van Dyke and published by Elsiever Science Publishers, B.V., this conference record fills two volumes and over 1,900 pages. Subjects, authors, and titles are available in Volume I.

PHYSICS

Getter Metallurgy, Vacuum Technology, and Gas Purification at SAES Getters in Milano, Italy

by Marco S. Di Capua, the Liaison Scientist for Physics in the Office of Naval Research European Office. Dr. Di Capua is an experimental physicist on leave from the Lawrence Livermore National Laboratory of the University of California.

The Company

SAES Getters (SAES), founded in 1940 as the Societa Apparecchi Elettrici e Scientifici, is an Italian company headquartered in Milano, Italy, (750 people worldwide). SAES is a leader in research, development, and application of getter techniques to maintain vacuum in: electron tubes, scientific instrumentation and metal vacuum insulated containers for consumer and industrial applications. SAES operates a well-equipped R&D central laboratory (about 50 people), and the company is unusual since it exports 98 percent of its production.

Gettering Technology

Alkaline metals and alkaline earth metals that come in contact with active gases form stable compounds arising from a strong chemical affinity. In the assembly of devices that must operate in a good vacuum (1.0E-08 - 1.0E-09 Torr), an alloy carries these metals, in inert form, into the vacuum envelope. In a typical manufacturing operation, an external pump pulls the initial vacuum, and the device is sealed from the outside world. Heating of the alloy releases the metal which condenses on the walls of the device. The thin metal coating, called the getter, then freely reacts with residual gases remaining after manufacture or with outgassing products released during operation. This technique, first applied to the mass production of radio receiving tubes, has found an even larger volume application in the manufacture of color and monochrome cathode ray tubes (CRTs) for television receivers.

In a CRT, the goal is to maintain a rest pressure of 1.0E-06 Pa or better, and, to sequester O_2, H_2, H_20, CO, and CO_2 that would eventually poison the cathode (Della Porta, 1972). In this application, heating a $BaAl_4$--Ni alloy, frees Ba as a vapor that condenses in the walls of the device. The Ba continuously sequesters the contaminants as stable compounds throughout the lifetime of the device. The other product, an AlNi compound, is stable and plays no further role in the gettering process.

An important activity of the research and development (R&D) laboratory is to help CRT manufacturers to assess the quantity of getter material required to perform the pumping task over the lifetime of the device (Sciuccati, 1988), determine the long-term compatibility of the getter with other materials within the CRT, and to refine the gettering technique for new technologies such as high-definition television (HDTV) displays, or high-brightness television projection displays that require high-current density cathodes.

Metal Dispensers

Advances in alloy metallurgy have also led SAES to develop dispensers for metals such as Hg that is essential, in gaseous/plasma form, for operation of Hg vapor rectifiers, plasma displays, and fluorescent tubes (Della Porta, 1972a). Heating the Ti-Hg alloy dispenser to 800°C, releases Hg in the sealed-off device. The Hg dispenser can incorporate a gettering material for fluorescent lamps applications.

The gettering technique is also essential in the manufacture of high-intensity lamps that reproduce the solar spectrum, and, high-efficiency lamps that yield a maximum of lumens per watt (Della Porta, 1972b). Combinations of gettering, to remove unwanted contaminants, and, gas dispensing to deliver the working gases, allow a very strict control of the gaseous atmosphere composition within the lamps. A long lifetime with a constant light output require such control.

Similarly, SAES applies this technology to dispensers of alkali metals. These highly reactive metals (Li, Na, K, Rb, and Cs) are the low work function emitter (photosensitive) surfaces in x-ray image intensifiers, night vision tubes, photomultipliers, fast photodiodes, and sources of

negative ions. In this application, the alkali metal appears in a mixture of an alkali metal chromate and a reducing compound. Heating the mixture achieves a controlled release of the alkali metal by reduction of the chromate.

Nonevaporable Getter Pumping Systems

In another area of metallurgy, SAES develops nonevaporable getters (NEG) for applications in which condensation of a Ba film onto the walls of the device is unacceptable. Zr is well established for this application. SAES, through metallurgical research, has developed Zr-based alloys that meet specific requirements such as pumping selectivity and operating temperature range.

To increase the surface to volume ratio and hence the pumping speed and capacity, metallurgical developments have also led to porous alloys with large surface-to-volume ratios. Techniques to coat the getter material on a strip that folds in concertina fashion, provide compact, high-volume pumping. Such strips make efficient use of space and economical use of the gettering alloy. For example, the Toroidal Magnetic Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory uses concertina geometries (Ferrario, 1977).

The Large Electron Positron Storage Ring (LEP) Pumping System. Electron storage ring applications require continuous pumping of the outgassing gas load that arises from impact of radiation on the walls. In other electron storage rings, linear sputter ion pumps that use the bending magnetic field provide the pumping. In LEP, at CERN, Geneva, Switzerland, the bending fields are too weak for efficient pump operation. Instead, 22 km of NEG strip (a Constantan ribbon covered by a cold sintered Zr-Al alloy, supplied by SAES) occupy a pump chamber located side by side with the main accelerator chamber. The NEG strip operates near room temperature maintaining a pressure of 1.0E-10 Pa during accelerator operation, providing all the pumping capacity in the 1.0E-08 and 1.0E-10 Pa pressure range. The NEG takes over from sputter ion pumps whose pumping speed drops very rapidly for pressures in the 1.0E-07 - 1.0E-08 Pa range. Auxiliary sputter ion pumps still remove CH_4 and rare gases which do not adsorb on the NEG.

The NEG and the auxiliary sputter ion pumps are the only pumping system in LEP. Mobile pumping systems provide the initial vacuum during a bakeout cycle at 150°C. When a current through the Constantan heats the ribbon to 450°C, molecules adsorbed on the NEG surface migrate to the interior of the getter. This exposes a fresh getter surface for a new pumping cycle at room temperature. The LEP estimates that 20 years of accelerator operation will require 10 to 20 NEG reconditioning cycles (Picasso, 1989).

Gettering techniques also find application in advanced and compact synchrotron light sources. Halama (1988) reviews recent advances in this application.

Vacuum Container Applications

SAES is also responsible for getter developments that allowed mass production of metallic, thermally insulated containers (Dewars or Thermos bottles) (Boffito, 1987). Vacuum, in such double walled containers, provides the thermal insulation. Fragile mirrored glass has been the traditional material for these Dewars. Getter materials, developed by SAES for use in all-metal, vacuum-jacketed containers, now allow production, at a reasonable cost, of sturdy, vacuum-insulated metallic containers for the consumer market. The same technology applies to cryogenic containers and vacuum-insulated piping for industrial applications.

Gas Purifier Applications

Research on gettering alloys has also led SAES to develop purifiers (Succi, 1989) to control gas contaminants in the part per billion range. The manufacture of megabyte memory chips requires these purity levels. The challenge in this application is to reduce the partial pressure of selected gas contaminants in the presence of large concentrations of a diluent gas. Developing and integrating of purifiers requires a systems approach since outgassing--like processes (Succi, 1988) in different elements of the gas storage and transport system release a variety of contaminants. These processes are similar to outgassing in conventional vacuum systems. The SAES R&D laboratories actively research this area.

Sputtering Targets

SAES supplies special alloy metal targets (Manini, 1988) as sources for sputtering of high-temperature superconductive films (YBCO). Development of these sources is a natural development that relies upon SAES's wealth of experience in the metallurgy of exotic alloys.

Research on Outgassing

Other research addresses the measurement of outgassing rates for thermal insulation at elevated temperatures in a vacuum environment (Sciuccati, 1988a). This research determine the outgassing rates for 304 stainless steel, cold-rolled Al foils, borosilicate glass fibers, alkali-free glass wool, and ceramic fiber paper with no binders. With some qualifications, 1 m^2 of stainless steel surface outgasses at the same rate as 6 m^2 of aluminum foil, 60 g of fiber glass, 170 g of ceramic fiber paper, or 310 g of glass wool. A measurement of outgassing rates allows the prediction of pressure versus time characteristics of sealed devices as well as optimal temperature-time schedules for the bakeout of devices that incorporate these materials.

Conclusions

This report emphasizes how SAES capitalizes on R&D within a specialized sector of metallurgical knowledge developed over the course of a half century. A blend of science, technology, and proprietary knowledge establish SAES as a world leader in passive pumping for systems ranging from vacuum bottles to accelerators that explore the frontiers of physics knowledge.

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The Third International Conference on High Dynamic Pressures, France

by Marco S. Di Capua

The Third International Conference on High Dynamic Pressures (HDP), France, sponsored by the Military Applications Directorate of the French Atomic Energy Commission (CEA-DAM), was held on June 5-9, 1989, at La Grande Motte, near Montpellier, France. There were 100 participants at the conference, which is the third in an 11-year cycle (1967, 1978, 1989). Roger Cheret, who has recently transferred from the Limeil Valenton Center to the CEA-DAM headquarters at the Rue de la Federation in Paris, chaired the conference. The better-known members of the Advisory Committee are Robert Dautray, CEA-Headquarters (see *ESNIB* 89-09:75-76), Harold Agnew, a former director of Los Alamos National Laboratory (LANL), New Mexico, and Jean Boisson, Inspector General for Powders and Explosives, French Ministry of Defense, (see *ESNIB* 89-09:43-44). Proceedings for the conference are available (CEA, 1989) from the French Pyrotechnical Association.

The HDP conference is rather unusual since the sponsor is a mission-oriented agency of the French government (CEA-DAM). There was a large participation from the CEA-DAM laboratories; therefore, it was considered their conference to a large extent. In his closing remarks, Cheret told the audience that the financing of the conference by the CEA-DAM required the blessing of the highest authority of the CEA. He suggested that, at this time, the leadership of the CEA places a very high value in international visibility of the French program in the physics of HDP; i.e., the behavior of explosives and the flow of metals in pressure fields whose intensity greatly exceeds the metal yield strength. In this context, it is puzzling that only one or two CEA-DAM scientists presented papers at the APS Albuquerque Conference on Shock Compression of Condensed Matter that discussed similar topics (nn, 1989). However, some were present at the detonation symposium in Portland, Oregon, two weeks later.

Overview of Participating Organizations and their Mission

In his keynote address, General Jean Boisson fleshed-out the organizational structure of detonics research and development in France. An article in *ESNIB* 89-09:43-44 provides Boisson's view of the delicate interrelationship of civilian, military, and CEA-DAM detonics research organizations and clarifies a large number of acronyms associated with French detonics organizations.

The *ESNIB* has recently discussed visits to two CEA-DAM laboratories: the high explosive testing center at Moronvilliers near Reims (*ESNIB* 89-04:57-59) and Centre d' Etudes Scientifique et Technique d'Aquitaine (CESTA), the vulnerability testing facility near Bourdeaux (*ESNIB* 89-04:59-60). The location of the Vaujours facility, which officially concentrates on nuclear fission, is a fort, built in 1875, in Courtry, the eastern suburbs of Paris. Once I did ask about the connection between the work done at Vaujours and the solid nature of the fort. The answer I got is: "Because the walls of the fort are thick!" The two facilities, Vaujours (18 participants) and Moronvilliers (5 participants), fuse administratively under the Vaujours-Moronvilliers (CEA/CEV-M) designation.

The presentations from Vaujours were concerned with the mixing of gas and ejecta from shocked surfaces, shock propagation in turbulent media (B. Sitt); detonations in condensed explosives, detonations in porous media, refraction of shocks at interfaces with discontinuities of sound speed (J. Aveille); and experimental determination of equations of state for detonation products (N. Carion). These activities also form the core of the corpus of publications of the Vaujours center. The core includes work on gas guns and theoretical investigations of shocks in actinides as well. The papers from the Moronvilliers site dealt with laser and flash x-ray diagnostic methods in detonics research.

Six people from the center from Bruyeres-le-Chatel (CEA/CB3) participated in this HDP. However, CEA/CB3 presented only one paper on shock damage of Al/Ti alloys (J. Ansart). A review of the literature, as well as participation of CEA/CB3 personnel at recent conferences in the topic of materials at high rates of strain (Oxford in 1989 (Harding, 1989) and DYMAT '88 in Corsica (nna, 1988); *ESNIB* 89-07:35-40), indicates that there is a substantial interest at CEA/CB3 on the metallurgy of materials at high strain rates.

The CEA Limeil-Valenton Center (CEA/CEL-V) also sent a sizeable contingent to the meeting--13. The contributions of CEA/CEL-V were more along theoretical lines including:

- Analytical calculations of the intersection of arbitrary stationary shocks (J. Delville)
- The effect of phase transitions in hydrodynamic phenomena (H. Bernier, may be older work since bibliography reaches 1977)
- Calculations of reactive flows in the presence of strong shocks (A. Bourgeade)
- Rayleigh-Taylor instabilities in laser-produced plasmas (P. Holstein)
- Calculations of light gas gun performance (H. Bernier).

The CESTA had four people at this conference but presented no papers. The Ripault center, near Tours, had 1 participant at this HDP symposium and 13 participants at a concurrent conference on pyrotechnics (Douda, 1989).

The other sizeable French contingents were six participants from the National Superior School of Mechanics and Aeronautics (ENSMA), Poitiers (see *ESNIB* 89-09:44), and five from ISL, St. Louis (see *ESNIB* 89-03:40-42, *ESNIB* 89-08:50).

There was participation from U.S. Department of Energy laboratories with five scientists from Sandia National Laboratories Albuquerque (SNLA), five from Lawrence Livermore National Laboratories, California, and two from LANL. U.S. Department of Defense had two U.S. Navy participants, one from Office of Naval Research European Office and one from the Naval Surface Warfare Center (NSWC), Dahlgren, Virignia. There were two participants from the U.K.: one from Royal Armaments Research and Development Establishment (RARDE), Ft. Halstead and one from Atomic Weapons Establishment (AWE), Aldermaston; one from Israel and the U.S.S.R. Academy of Sciences.

Remarks About the Scientific Program

Notwithstanding, the CEA-DAM sponsorship, the Advisory and Organizing Committees assembled a balanced program. An overview of the program and of European papers, I found interesting, appears below. The U.S. presentations appear at the end of the report.

Gas Dynamics. B. Sitt, CEA-CEV-M, has developed a formalism that yields a model for shock propagation in turbulent media. According to Sitt, the main difficulties in the turbulent regime lie in casting the conservation relations. He proposes closure of the equations across the shock by decomposing the velocities and using asymptotic methods to account for the axial and transversal turbulent energy in the flow.

The interaction between ejecta from a shocked surface and a gaseous atmosphere appears to be a topic of great theoretical and experimental interest. G. Guri, CEA/CEV-M, described hydrodynamic ablation (stripping) of the ejected particles stops the particles over very short distances. He considers the two cases in which the

shock in the gaseous atmosphere runs ahead and behind the particles. Guri finds good agreement between the particle trajectories predicted theoritically and those measured experimentally.

The French National Research Center (CNRS) Detonics Laboratory at ENSMA discussed research on pressure pulse generation by a laser that heats a metal substrate confined behind a transparent cover. This technique, performed in collaboration with the Laboratory for Utilization of Intense Lasers (LULI) at Ecole Polytechnique (see *ESNIB* 89-09:75 and 76-77), produces 60 to 80 kbar in glass-Al and glass-Cu sandwiches for a 1.8-ns irradiation pulse at 25 GW cm^{-2} at 1.06 μm. Another paper from the same group (F. Cottet) displayed data on Al spall induced by laser irradiation.

Detonation of Explosives. There were several papers on experimental measurements on explosives with a range of densities: deflagration-detonation transitions in porous explosives (T. Hsieh, NSWC), detonations in nitromethane-polymethylmethacrylate loaded with glass microballoons (H. Presles, ENSMA), weak detonations in TNT/RDX/Si and boron nitride mixtures (A. Dremin, Institute of Chemical Physics, Moscow), and initiation and combustion of granular materials (M. Baer, SNLA).

J. Heuze, CEA/CEV-M, presented a paper, greatly appreciated by the audience, on a simple method to calculate the detonation properties of CHNO explosives. Heuze's method, assuming a fixed composition of the detonation products and a negligible volume of solid carbon in the products, leads to fast calculations for condensed explosives that agree well with predictions of a complete model and experimental data.

Hydrodynamic Code Calculations. G. Leiper, Imperial Chemical Industries Nobel Explosives, Stevenston, U.K., discussed very sophisticated hydrodynamics modeling of detonations where he takes explicitly into account chemical reaction rates for the explosives. With the LLNL DYNA2D code, Leiper divides the reaction zone into 3 to 20 meshes. Leiper finds that this approach provides a very reliable method to predict explosive performance.

An impressive paper by G. Luttwak, Rafael Armament Center, Haifa, Israel, described a Multi Material Arbitrary Lagrangian Eulerian (MMALE) code that calculates efficiently the hydrodynamic propulsion of thin shells in the pressure field of a high explosive. In this code, the grid motion can be arbitrarily prescribed so that the code exploits the advantages of a Lagrangian formulation up to the moment in the calculation where the deformations are so large that the mesh begins to entangle. At this point the calculation stops, the problem space is rezoned, and the calculation continues along a Eulerian scheme (G. Luttwak, nd).

In the proceedings, she demonstrates the merits of the approach with a shaped-charge calculation. According to a participant, R.L. Rabis and G. Loltwak presented some initial results at the 7th or 8th Detonation Symposium.

Equations of State. There were several contributions on equations of state (EOS). Perhaps the most interesting ones dealt with fundamental calculations for the molecular to metallic phase transition in hydrogen (P. Haskins, RARDE), analytical representations of EOS for quantum fluids such as hydrogen ad helium (W. Byers Brown, University of Manchester, U.K.), and EOS for solid Li at 0°K (G. Zerah, CEA/CEL-V).

Instrumentation. The ISL contributions (F. Bauer) dealt almost exclusively with the results of a joint program with R. Graham, SNLA, on improved pressure transducers [poly(vynilidene fluoride and trifluoroethylene)]. These are superior to the PVDF variety inasmuch as they exhibit a piezoelectric response that is a continuous function of pressure up to 30 Gpa. Other results of the collaboration concentrated in calibration of the PVDF transducers up to 24 GPa, demonstrating identical behavior between gauges made in France and the U.S. The data presented at this conference suggest that PVDF gauges, by providing large signal outputs proportional to stress rate over a wide pressure operating range, may very well become the preferred instrumentation up to 15 Gpa, and variants of these gauges may very well be useful up to 30 Gpa.

An optimization study of an image converter tube with a microchannel plate amplifier (J. Veaux) bears witness to the effort expended at the Moronvilliers site of the CEA/CEV-M to develop imaging instrumentation for their flash radiography facilities (see *ESNIB* 89-04:57-59). The 60-mm-diameter optimized tube, which feeds a fiber optic array at the output, is capable of detecting x-ray doses of less than a millirad in the 150 kV - 1 MeV energy range. Miss Veaux also coauthored, with P. Mercier, a paper on a transportable Laser Doppler Interferometer where a high power-pulsed multimode laser source permits velocity measurements on low reflectance surfaces.

U.S. Presentations

For completeness, the subjects covered by the U.S. presentations were:

- L. Moore, SNLA-Standardized PVDF gauges
- G. Bloom, LLNL-Shock initiation of high explosives by thin pulses
- A. Bowman, LANL-Interactions of jets and explosives
- R. Graham, SNLA-Review of shock-induced, solid-state chemistry
- M. Bauer, SNLA-Initiation of granular energetic materials

- P. Tang, LANL-Application of HE reaction model to assess booster performance
- J. Osher-LLNL 100 kV gun
- R. Lee-Modeling of electric gun performance
- D. Steinberg-LLNL, Rate dependent models and shock profiles in W
- D. Maiden-LLNL, Viscosity of solids under shock impact.

Conclusions

This meeting provided a glimpse of French activities in the field of detonics and HDP. Up to now, portions of their program has only been familiar to limited groups at some U.S. laboratories.

The papers presented at this meeting suggest that research in HDP is still a very much an applied subject. Development of new technologies may require a substantial investment in an inherently difficult area of basic science where calculations, experimentation, and instrumentation are exceedingly expensive. From this meeting, it appears that the CEA-DAM may be moving in this direction.

The only substantial papers on hydrodynamic calculations came from the U.K. (G. Leiper) and Israel (G. Luttwak). Consequently, the level of hydrodynamic code development in France for HDP applications is difficult to assess. However, France has a very strong tradition in applied mathematics; e.g., R. Dautray, a member of the steering committee is the author of an extensive reference textbook on Mathematical Analysis and Numerical Techniques (see *ESNIB* 89-09:75-76). I believe that, on this basis, the ability to perform complex hydrodynamic calculations must be as good or better as in any other country with a strong defense establishment. Therefore, it is possible that the French may perform calculations on modified commercial codes for which they have purchased the source.

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The 1989 High Energy Rate Fabrication Conference - Some Emphasis on Soviet Contributions

by Dr. Marco Di Capua

High Energy Rate Fabrication (HERF) '89, held at Ljubljana, the capital of the Republic of Slovenia (Yugoslavia) September 18-22, 1989, takes place in a 3-year cycle (San Antonio, 1983; Novosibirsk, 1986). The HERF conference discusses effects and applications of shock waves, and high-strain-rate phenomena on materials. These topics are similar to those covered in 5-year cycles by the EXPLOMET (Meyers, 1989) conference series. The HERF conference draws most of participants from Eastern Europe, including the Soviet Union, while EXPLOMET draws researchers from Europe and the U.S.

The HERF conference gathered 60 participants from the host country Yugoslavia, 45 from the U.S.S.R., 8 from the U.S., 7 from Poland, Hungary, and Czechoslovakia, and 10 from European Community countries at the Ljubljana convention center. The interpreters translated the Soviet papers into fluent English with ease. Registration, payments, room reservations, and list of participants where highly automated, confirming my observation of widespread application of informatics in Slovenia. In effect, electronic terminals are common in airports, hotels, banks, and stores. Business supply outlets as well,

display a large choice of personal computers, accessories, software, and manuals.

The themes of the conference I found interesting were:

- Compacting of high T_c superconductors
- Explosive welding, hardening, and cladding of materials
- Some unusual views on mathematical modeling
- Soviet technology developments and applications.

S. Petrovic, the conference chair, distributed the proceedings on the first day of the conference (nna, 1989).

Compaction of High T_c Superconductors

The meeting devoted significant attention explosive shock compaction of high T_c superconductors. This technique offers some advantages in preparing monoliths to near final form, starting with rigid ceramic powders. The goal is enhancing connectivity of the superconducting particles by increasing the density of the compacted material. This enhanced connectivity may hold a key in the quest to raise the current conducting capacity of high T_c superconductors. So far, the shock treatment appears to lower the critical current. However, partial recovery is possible by annealing the material after compression. The August 1989 Topical Meeting on Shock Compression of Condensed Matter in Albuquerque, New Mexico, (nnb, 1989) also covered this topic in some detail.

K. Staudhammer's research, Los Alamos National Laboratory, New Mexico, and Fraunhofer Institute for Applied Materials Research, Bremen, Federal Republic of Germany (FRG), tried to determine whether the low-critical currents measured in shock compacted materials arise from the explosive compaction process or with the raw powder itself. Staudhammer found shock parameters that yield crack- and melt-free $YBa_2Cu_3O_{7-x}$ parts with densities greater than 94 percent of the theoretical density. This suggests that the low critical current may be a property of the raw powder.

A paper of L. Murr, now at the University of Texas at El Paso, discussed the optimization of the encapsulation and consolidation of superconducting powders into monoliths with an explosively welded copper matrix. Murr emphasized the difficulty in identifying the explosive forming process trajectory that increases the compaction of the powder, optimizes the welding of the matrix, and maintains (and, perhaps enhances) the properties of the superconducting material itself. Introducing defects that pin magnetic flux vortices increases the critical current thereby enhancing the superconducting properties. Murr and Alan Hare, Northwest Technical Industries (NTI), Sequim, Washington, performed pioneering work on explosive compaction of high temperature superconductors and hold a patent on the process.

A. Szalay, Research Institute of the Electrical Industry, Budapest, Hungary, talked about high-T_c superconducting rings to measure magnetic fields below 10 μT with SQID devices for medical diagnostics.

After the session, A. Deribas and V. Nesterenko, Special Design Office of High Rate Hydrodynamics, U.S.S.R. Academy of Sciences, Novosibirsk, who also delivered papers at the Albuquerque meeting, emphasized that investigations of shock processing of high T_c superconductors ought to continue. They feel that progress in other facets of high T_c research may suggest an optimal trajectory for shock processing in pressure, density, and time. Finding this optimal trajectory is a laborious process requiring large investments. However, a large possible payoff may justify the investment.

Superconductor compaction through the impact of a projectile launched with a light gas gun (see *ESNIB* 89-04:31-35), by guaranteeing tightly controlled and reproducible conditions, may be the avenue that leads to an optimal compaction path. In particular, C. L. Seaman (Seaman, 1989), University of California, San Diego, in collaboration with W. Nellis group from Lawrence Livermore National Laboratory (LLNL) (Weir, 1989), compacted a few tenths of a gram of high T_c powder at peak pressures in the 30-200-kbar range in μs time scales with a projectile launched from the LLNL two-stage light gas gun. Seaman produced an orderly configuration of crystallites with smooth intercrystalline boundaries. Seaman created, at 167 kbar, the flux-pinning sites that raise the critical current density in the material to 320 A cm^{-2}. The flux-pinning sites remain after annealing the material above 900°C. According to Nellis, explosive compaction of larger samples could reproduce the pressure-volume-time trajectory the gas gun delivers.

Explosive Welding and Processing of Materials

A View of Soviet Efforts. The Soviet speakers and their organizations that stood out in these areas at the meeting were:

A. Deribas, Special Design Office of High Rate Hydrodynamics, showed a variety of chamber designs for explosion containment. Deribas has now completed the design of the penetrations for an existing 16-m diameter chamber with 30-cm thick walls, for V. Fortov, Institute for High Temperatures (see *ESNIB* 89-10:33-35), to contain explosions in the 500 to 1000-kg range.

Deribas' presentation emphasized mass production of parts, such as hardening of the blades (frogs) of railway track switches, through explosive processing in chambers. Deribas can supply, for hard currency, the chambers built by his institute.

V. Nesterenko, Special Design Office, described processing of amorphous magnetically soft foils into parts for

electronic applications. Nesterenko also showed that explosive compaction could form motor armatures with magnetically hard Mg-Al-C alloys. Annealing of the compacted part recovers some of the residual induction lost during the compaction process.

I. Maticin, Lavrentiev Institute of Hydrodynamics, described compaction of ceramic insulators that incorporate concentric metal-ceramic-metal seals for high power lasers. Calculations with the HEMP finite difference code, performed by M. Wilkins, LLNL, determined the configuration of the explosive, ceramic, and metal for compaction.

L. Pervukhin, ANITIM NPO State Corporation, Barnaul, 300 km SE from Novosibirsk, described cladded products such as stainless steel-on-steel, aluminum on steel, titanium on steel, bronze on steel (bearing applications), and tool steel-on-steel. ANITIM's products aim at the chemical process and agricultural industry emphasizing frugal use of the valuable material. ANITIM, who also designs and constructs explosive containment vessels, also wishes to market its products in the West.

A. Derzhavets, All-Union Research and Designer's Institute on Explosive Methods of Geophysical Exploration, Ramenskoye (Moscow), talked about arrays of oil well casing perforating charges, explosively driven diverters for down-hole oil recovery, and explosive and detonator compositions that operate reliably at 250°C temperatures and pressures of 750 MPa. A very recent, lavishly illustrated 94-page catalog describes their products in detail (nnc, 1989) underlining a strong desire to open a market for its products.

V. Petushkov, E.O. Paton Welding Electric Welding Institute, Kiev, performs microstructural analysis of explosive welds. This work appears out-of-date.

I.V. Yakovlev, Lavrentiev Institute of Hydrodynamics, Novosibirsk, U.S.S.R. presented very clean, time-resolved measurements of temperature and pressure excursions of shock compressed Ti powders reinforced with Mo fibers. The aim of his research is to understand how the Ti matrix "wets" the Mo, providing a reliable fiber matrix bond.

Academician V.Y. Panin, Institute for Physics of Hardness and Materials, Tomsk, discussed some revolutionary ideas (Panin, 1987) on production of highly excited states in crystals by very high-rate deformations. Panin, regards a crystal-undergoing-plastic deformation as a nonhomogeneous, highly nonequilibrium system that advances to equilibrium as the stress-gradient field drives structures through the crystal. In particular, Panin suggests that shear deformations in a crystal propagate, across grain boundaries, through oscillatory shear waves, to neighboring crystals. Translational flow vortices support waves of plastic deformation in the solid. These propagate at a much faster rate than diffusion-driven deformations. Panin suggests that the dynamic deformation process produces highly excited states in the crystal that alters the interatomic potentials. Panin hopes to discuss some of these models at workshop in Terscol (Caucasus, U.S.S.R.) (Psakhie, 1989) on "New Physical Methods of Investigations of Materials Under Loading."

G.V. Sakovich, Lavrentiev Institute of Hydrodynamics, described the synthesis of diamond clusters through a process where pressure rises to 20-40 Gpa in 1 μs and temperatures attain 3500-4000°K in explosives bearing organic compounds, such as benzene and acetone. Sakovich's claims achieve an almost complete conversion of free C into the diamond phase. V. Titov's laboratory in Novosibirsk is designing a pilot plant to produce diamond dust in industrial quantities for wear-resistant coatings on machine parts, as well as for grinding and cutting compounds.

A. Antipenko, Institute of Chemical Physics, Chernogolobka (Moscow), performed detailed measurements of the detonation speed in RDX and TNT as a function of density. He associates a plateau that appears in the curve as the density increases, with the change of free C into diamond. V. Drobishev produced a higher yield of diamonds in soot-loaded explosives (amorphous C) than in graphite-loaded explosives (crystalline phase C). These results suggest that the rearrangement into diamond of the crystalline structure of graphite is energetically unfavorable. The optimal C fraction in the production process is a trade secret of the Moscow and Novosibirsk groups.

Some Western Efforts

Explosive cladding of materials appears to enjoy a renaissance, filling requirements of the aerospace industry to bond unique material combinations such as Ti-Al or unusual geometries. In particular, R. Hardwick, ICI Explosives, Stevenston, U.K., discussed a simple method to produce multilaminar composites. In this method, a sheet of explosive drives a massive plate that collides with the laminae, maintaining the steepness of the collision angle between the plates. Hardwick also suggested an interesting technique to roll the resulting clad billet. When the yield strength of the two layers of material is different the rolling process curls the sheet. Rolling two sheets face-to-face simultaneously, cancels the curling forces, allowing the plates to exit the rollers free of distortion. This approach successfully produced, for the chemical industry, large plates of Hastealloy clad steel.

With another technique, ICI assembles steel joints on Al pipes in a production environment with explosive swaging. Al pipes are lighter and support larger deflections than steel pipes allowing greater freedom in directional drilling of oil wells. For durability, however, these pipes require steel joints.

Summary and Conclusions

Discussions with U.S. and U.K. colleagues at the meeting centered upon assessing the Soviet presentations. A consensus developed that in many instances, Soviet researchers devote large resources to repeat published Western research. So some of the papers submitted to this HERF symposium have lost historical perspective.

Many Soviet papers on explosive welding and processing of materials, such as hardening, suggest that application of these techniques may be wider in the U.S.S.R. than elsewhere. In Western economies, explosives' use falls under very tight, and therefore expensive, safety and environmental restrictions. In the Soviet economy, there are no resource distributing market processes to force a selection of efficient fabrication methods. Moreover, environmental and safety regulations are weaker than in the West. Therefore, easily accountable material costs have a larger impact in the choice of industrial processes.

In contrast, commercial success of explosive processing in Western economies, depends on:

- Cheap raw materials
- Valuable final product
- No alternative fabrication methods
- A large market for the final product that affords economies of scale.

These considerations restrict explosive fabrication to unique assemblies such as Ti to Al composites, or to recondition parts that already incorporate a very large processed value. One example is remanufacture of built-in bearing races in helicopter rotor shafts.

In the U.S there are three companies active in explosive processing: Explosive Fabricators, Louisville, Colorado; NTI, Sequim, Washington; and the specialty explosives division of E. I. DuPont. DuPont has been producing polycrystalline diamond powder by explosive synthesis (Beard, 1988) for more than 15 years in an underground limestone mine in Pennsylvania. Development also takes place at national laboratories (Livermore, Los Alamos, Army Aberdeen Ballistic Research Laboratory.) The Center for Explosives Technology Research (CETR) in Socorro, New Mexico, associated with the New Mexico Institute of Mining and Technology, Socorro, also performs explosive processing research.

In the FRG, Sur Met, Aachen, performs high HERF processes in closed chambers. Sur Met was absent at this conference and the capabilities of its facilities are unknown. In Japan, Akira Sawaoka of the Tokyo Institute of Technology, Yokohama, is also active in this field.

Future developments in material compaction will probably emphasize planar geometries that avoid the radial dependence of processing path in cylindrical geometries. Compaction may involve cold isostatic pressing followed by final compaction by a shock wave (Beard, 1988). Explosive processing may also be useful in compaction of polycrystalline materials, such as artificial diamonds, where large temperature excursions alter the structure.

Researchers may be able to determine using gas guns, for example, optimal trajectories in pressure-volume-time space that allow appropriate relaxation processes to develop during compaction. These optimal trajectories afford some control over the compaction process. Molecular dynamics calculations of excited states in crystals may shed some light on what the optimal trajectories may be. A knowledge of the optimal trajectory will allow tailoring of the explosive compaction process.

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NATO Advanced Study Institute on Chemistry and Physics of the Molecular Processes in Energetic Materials

Two researchers, separated by the Atlantic Ocean, can view a conference from different perspectives. In this issue, we present two summaries of NATO Advanced Study on Chemistry and Physics of the Molecular Processes in Energetic Materials, held on September 4-15, 1989, in Altavilla Milicia, Sicily. J. Sharma presents the American viewpoint; he is a research physicist at Naval Surface Warfare Center, White Oak, Silver Spring, Maryland. J. Boileau, consulting scientific advisor to the French National Company of Powders and Explosives, Paris, presents the European viewpoint.

AN AMERICAN PERSPECTIVE

J. Sharma

Introduction

The NATO Advanced Study Institute on Chemistry and Physics of Energetic Materials (explosives and propellants) was held at Hotel Torre Normanna, Altavilla Milicia, Sicily, September 4-15, 1989. The meticulously planned conference was organized by Dr. S. Bulusu, Armaments Research, Development, and Engineering Center (ARDEC), Dover, New Jersey. Dr. Bulusu has been active in the energetic materials field for more than 25 years with particular interest in characterizing the decomposition reactions of energetic materials. The thrust of the conference was to create a better understanding of energetic materials from a fundamental molecular point of view.

The 10-day conference involved 4 or 5 lectures each day, providing the presenters with plenty of time to present their results. Of the 21 speakers, 15 were from the U.S., 2 from the U.K., and 1 each from Canada, the Netherlands, Federal Republic of Germany (FRG), and Israel. Besides the speakers, there were about 50 attendees from the above-mentioned countries and from Portugal, Spain, Belgium, Italy, Turkey, and Greece. For the benefit of participants without any background in the energetic materials, the speakers gave ample introduction to their techniques and methods. The scenic beauty of the conference site and the participation of very distinguished speakers made the meeting a great success. The meeting will undoubtedly have a significant impact on future trends in explosives and propellants research.

With the development of specialized weapons systems and an emphasis on new heavy load boosters for space missions, the performance expectations of energetic materials have become more demanding. Through a sound scientific understanding of the factors controlling performance and safety, the rising expectations can be met. The well-balanced conference program presented current advances in theory and experiment, providing valuable information to the attendees for the development of superior and safe systems.

General Session

The first talk was given by Professor P. Gray, Cambridge University, U.K., who discussed the problems of thermal ignition. Besides giving the background of the topic, he developed his theory leading to the questions of subcritical, critical, and supercritical situations in explosives. He talked about models of isothermal chemical oscillations and chemical wave propagation in a closed system. His theory had applications not only to energetic materials but also to the situation of pigs dying in hot weather, because they cannot dissipate heat by body perspiration.

Professor Gray's talk was followed by that of Dr. Carl Melius, Sandia National Laboratory (SNL), Livermore, California, dealing with molecular quantum mechanical calculations for reaction pathways. By using the information of chemical species from spectroscopic data, he uses Hartree-Fock calculations of free energy, combines it with perturbation theory to calculate electronic energy, bond additivity, and bond energies. He folds these with statistical mechanics and entropy calculations by an iterative process, which can take as many as 100 hours on a Cray computer for a single molecule. He discussed his results with special emphasis on HMX and RDX, the relative stabilities of their ring structure and the role of a catalyst like water. In HMX, the N-NO_2 bond breaks first, but then the ring becomes very weak.

The next lecture was that of Professor Simone Odiot, Universite Pierre Marie, Paris, who combined Quantum Chemistry and Molecular Dynamics to elucidate picosecond mechanisms and microscopic theory of detonations. She has combined the molecular approach with crystal considerations. She discussed intermolecular weakening

of bonds and cooperative mechanisms, which should show up in the detonation velocity having different values in different directions of the crystal. This should encourage work on single crystal explosives. She introduced the interesting concept of the density of NO_2 in the molecules as a criteria for explosiveness, so that if it is less than 0.47 mole fraction, the molecule will not explode.

Molecular Decomposition Studies

Professor Jehuda Yinon gave an elegant talk on mass spectrometry in general and discussed its application to energetic materials. He especially discussed tandem mass spectrometry, which would give results of collision-induced dissociation. He dealt with the fragmentation pattern and pathways of different explosives.

Another talk on mass spectrometry was delivered by Dr. R. Behrens, SNL, who described the results obtained in his unique setup. He uses simultaneous thermogravimetric modulated beam mass spectrometry and time-of-flight velocity spectra in order to neatly eliminate the confusion arising out of electron impact effects during the study of thermal fragmentation. By clever experiments and by using isotopically labelled HMX, he is able to follow the pyrolysis reaction products during different stages of decomposition. His results show that N_2O, CH_2O and H_2O are most abundant; CO, NO, and HCN are less and the amounts of C_2H_5NO, $C_2H_6N_2O$, and ONTNTA are the smallest. He has extended his studies to cover pressure range up to 1000 PSI and temperature up to 800°C.

Professor Tom Brill, University of Delaware, Dover, discussed his results on rapid thermal decomposition studies monitored by Fourier transform infrared spectroscopy. He could heat his samples as high as 800°C/s and at pressures of various blanketing gases as high as 1000 PSI. Brill studied the effects of argon gas pressure on the fast decomposition. He found that a lot of reactions take place in the condensed phase. In the case of RDX, the generation of NO_2 decreases with time while that of NO and HONO increases.

Drs. Normand Blais and Roy Greiner, Los Alamos National Laboratory (LANL), New Mexico, described their novel experiment; the shock wave generated blowoff material was analyzed with a mass spectrograph giving information on the prompt reactions in particles flying in vacuum at a speed as high as 10 km/s. This corresponds to the regime between Von Neumann spike and C-J expansion. They reported studies on TNT, RDX, HNS, TATB, PETN and solid NO, nitromethane, and acetylene. A clean distinction in the products from oxygen-balanced and -deficient explosives was reported.

Dr. Fred Volk, Fraunhofer Institut für Chemische Technologie (ICT), FRG, discussed more practical aspects of detonation products as seen in different explosives such as ideal, nonideal, plastic-bonded explosives; underwater high explosives; heat-resistant and commercial explosives. He considered the effects of gas or self-confinement and compared his results with calculations based on different codes. He reported about the formation of diamond particles in the soot. The diamond is found to trap nitrogen and hydrogen in it. The presence of nitrogen is not a surprise but trapped hydrogen was not expected. Dr. N. Roy Greiner, LANL, also reported the presence of diamonds in the soot from explosives.

Reaction Pathways and Projectile Impact

Dr. John Connor, Royal Armament Research and Development Establishment, U.K., slanted his talk in the direction of real applications. He drew attention to the fact that initiation is a notoriously difficult problem to study, reactions are rapid, the reaction pathways are numerous and complicated so that both experimental methods and theoretical studies are usually not adequate. He described some of their efforts to use *ab initio* molecular orbital calculations to describe equation of state from first principals and to relate this to the cases of nonideal systems. He addressed the problem of sensitization of nitromethane by the presence of amines. Another topic to which he drew attention was the urgent practical problem of ignition or initiation of explosives or propellants by projectile impact. The projectile can cause detonation, violent deflagration, burning, or have no effect. Adequate models or small-scale predictive tests do not exist. Connor described a small-scale fragment impact test, which may be very useful. He also considered nondetonative explosions.

High-Pressure Studies

Dr. Gasper Piermarini, National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, gave an elegant talk on the development of diamond anvil as a means of generating high hydrostatic pressure for studying the behavior of materials. He has been a pioneer in the development of the technique. According to Dr. Piermarini, pressures as high as 3.5 Mbars can now be produced in the laboratory. Because of transparency of diamonds to light and x rays, optical spectroscopies and diffraction techniques can be applied *in situ*. The temperature can be varied in the range of 77-1000 K. Dr. Piermarini described his experiments with explosives such as HMX, RDX, and nitromethane in the pressure regime up to 40 kbars. He reported on the phase transitions in HMX, its unimolecular decomposition during heating, and the negative pressure dependence of the thermal decomposition. In nitromethane, he found bimolecular decomposition and observed stress-induced catastrophic decomposition to solid residue. Phase I

RDX showed a positive pressure dependence on thermal decomposition. Perhaps someday he could rapidly change his pressure in the cell by using something like piezoelectric drivers, so that changes in explosives during rapid increase and decrease of pressure could be studied. Piermarini's results are valuable because during initiation of explosives by shock, reactions do take place under high pressure.

Laser Irradiations

Dr. B.J. Van der Meer, Netherlands Institute for Applied Scientific Research, Prins Maurits Laboratory, Rijswijk, the Netherlands, reported on emission spectroscopy as a tool to detect decomposition products on a nanosecond time scale from laser irradiated explosives, using excimer, Ruby, and CO_2 lasers. He reported on both primary and secondary explosives, and his results deal with photothermal, photoshock, and photochemical reactions. In the case of primary explosives, breakup into the elements was common, while in the case of secondary explosives, CN, CH, OH fragments were observed.

Hot Spots

Dr. Jagadish Sharma, Naval Surface Warfare Center, Silver Spring, Maryland, described his experiments in which by using a Scanning Electron Microscope (SEM) and x-ray photoelectron spectroscopy (XPS) he has detected hot spots and determined their physical and chemical nature. Hot spots were proposed in 1952 by Bowden and Yoffe in order to explain the ignition of explosives by mechanical stimuli and are blamed for sensitization of explosives caused by rough handling and consequent accidents. However, on account of their small size and the minute concentration, hot spots could not be observed. Sharma has identified them in explosives recovered from the verge of ignition. The SEM micrographs have shown submicron and micron size reaction sites in the shape of ragged holes, surrounding which reaction products are found deposited. The XPS has revealed two kinds of products. One is more sensitive than the explosive, and the other is produced by the creation of a water molecule from the explosive. The first product causes sensitization, and the second step supplies energy to sustain the reaction from the exothermic production of water. For example in TATB, furoxan and furazan derivatives have been observed. Furoxans are far more sensitive than TATB, and the furazan is produced by the separation of a water molecule. Products resulting from similar reactions have also been identified in the case of other explosives. These findings, by giving a simple explanation of sensitization in terms chemical changes, have resolved a long-standing mystery. The results not only explain the major steps of the ignition processes, but also explain the induction period of thermal decomposition and behavioral changes of explosives caused by radiation damage. Sharma's results parallel the kinetic isotope effect results observed by Shackelford and others for slow thermal decomposition demonstrating the similarity of products formed under fast and slow reaction conditions. Hot spots and the reaction products have been found to be concentrated on the surfaces of the crystallites. This would support the dislocation theory of initiation that Coffey proposed.

Molecular Structure and Sensitivity

Dr. Carlyle Storm, LANL, gave an elegant and educational talk on sensitivity in relation to the structure of the molecules. This is a subject over which a lot of people have speculated; both empirical and more enlightened ideas based on the structure and reactions have been proposed. Dr. Storm has gone through a study of more than 250 compounds to gain an intelligent perspective. If sensitivity can be understood in relation to structure, then one can control it through appropriate molecular design and manipulations. Besides other molecules, he gave an elegant explanation of how TATB can go into sensitized form by conversion to furoxan and how conversion into furazan restores the insensitivity of TATB while releasing about 59 kcal/mole of energy. He gave an important moral. In order to achieve insensitivity, an explosive should be given a series of intermediates during breakup providing the explosive with a chance to stabilize.

Kinetic Isotope Effect

Dr. Scott A. Shackelford, U.S. Air Force Academy, Colorado, reported on the Kinetic Deuterium Isotope Effects (KDIE) for the study of decomposition processes involved in the combustion and explosion of energetic materials. Kinetic isotope effect is a direct way to determine the rate-controlling mechanism during slow or fast decomposition, including thermal ignition. At first, he clearly defined ranges of theoretical and experimental values when the effect is direct or indirect; then he described application of the method to a series of explosives (TNT, RDX, HMX, TATB, DINGU, and PETN). The KDIE can be positive or negative depending upon the state of the explosive. His results show that decomposition process can mirror rate-limiting features in combustion of propellants. This fact is not, at present, considered by rocket designers. There was a clear similarity between the results of Shackelford with those of Sharma based on XPS studies.

Dr. Sam Trevino, ARDEC, at NIST, described neutron scattering experiments which can give precise measurements of torsional vibrations in materials like nitro

methane. The activation energy for these vibrations are in the 200 cal/mole regime. He mentioned that the analytical capability at Grenoble has micro eV-resolving power, so that deuterium isotope shifts and pressure effects should be measurable.

Dr. Robert A. Marino presented a talk on nuclear electric quadrupole and nuclear magnetic resonance NQR/NMR studies of explosives in solid phase. He reported on the polymorphs of ammonium nitrate and its orientational disorder. He had interesting results on polymer chain dynamics of nitrocellulose, especially the subtle changes in the region of its glass transition.

Molecular Architecture and Energy Output

Dr. Jack Alster, ARDEC, gave an exciting and lucid talk on the molecular architecture of energetic materials. He showed that by using beautiful geometries, higher densities can be attained which could lead to the development of more powerful explosives. He discussed that strained ring compounds and strained cage compounds and their combination potentially could give higher pressure yields. He is using these results to push hard in his progress towards realizing octa-nitro cubane or compounds close to it, which will be more powerful than present nitro compounds based on six- or eight-member rings. His arguments are very convincing, and he substantiated them by citing his results on tetra-nitroadmantine which has met performance predictions.

Theoretical Lectures

Besides talks on physical and chemical properties of energetic materials and methods to understand their behavior, there were quite a few lectures on theory. Professor Sandor Fliszar, University of Montreal, gave a highly educational and brilliant talk dealing with dissociation energies in reference to explosives. He used Hellmann-Feynman theorem from which energy expressions can be derived for individual bonds. His talk was a guided tour into the world of bond energies in which he showed that association and dissociation energies can be different. To clarify his point, he gave the example of a rubber balloon that might need considerable amount of energy to assemble, but all it needs is a tiny pin prick for its explosion. In his second talk, he discussed the application of X-alpha Local Spin Density approximation in the study of organic molecules in general. He showed that with proper choice of alpha, evaluation of dissociation energies is well within experimental accuracy.

Professor Peter Politzer, University of New Orleans, Louisiana, gave talks on *Ab Initio* Self-Consistent-Field molecular orbital approach for energetic materials. He stressed on the role of Coulomb potential in the atomic spaces of the molecule which, he pointed out, can be used to interpret the stability of explosives. He explained the different sensitivities of various nitro-aromatic molecules, especially those of TATB family on the basis of charge flow and donating of resonance. In the second talk, Professor Politzer discussed the nitramines and strained molecules.

Dr. Don Tsai, Istar Inc., California, (formerly from NIST) gave two talks on molecular dynamics studies. In the first talk, he dealt with shock compression and the accompanying energy profile in nonreactive solid or dense liquid. The studies on diffusive and pulsed heating clarified results of second sound experiments and thermal relaxation processes in the shock wave profile. The mechanism of hot spot and dislocation formation became apparent. In the second talk, he dealt with a solid made from diatomic molecules capable of undergoing exothermic dissociation. The results elucidate the mechanism of thermal and shock initiation, thermoelastic coupling within the material, and the energy exchange between the molecules and their products. The last topic is very interesting, because probably soon it will become possible to verify the results with the help of picosecond chemistry.

Panel Discussions

There were two sessions of panel discussions. One was on the relationship between advances in science and poor fit with practical engineering problems in explosives. Engineers are concerned with effects of projectile impact and its quantification. They would like to know the environmental effects of temperature or weapon history. Prediction of such events are still very difficult from basic studies. Then there is the question of low vulnerability or insensitive explosives. From basic studies, it is not possible to predict how the projectile impact will effect an insensitive explosive. The second panel discussion, which took place on the last day of the meeting, tried to guess directions for future research. Of course, each panel member provided different ideas. Professor Gray suggested that sensitivity test should be improved; thermal explosions and experiments at high pressure should get more attention. Perhaps multiple hotspot model should be developed. He advocated the need of simple models to understand explosives. Sharma suggested that to study the development of hotspots from molecular size, the newly developed technique of atomic force microscope should be applied.

The proceedings of the NATO conference will be published by Kluwer Academic Publishers, Dordrecht, the Netherlands, and the book is expected to appear in the first half of 1990.

A FRENCH PERSPECTIVE

J. Boileau

Introduction

This NATO Advanced Study Institute (ASI), on the chemistry and physics of molecular processes in energetic materials is the third in a series on energetic materials. Previous meetings were held in Greece in 1980 (Capellos, 1981) and 1985 (Capellos, 1986). There were 71 participants; among them were 34 Americans, 6 French, 6 English, 5 Turkish, 5 Italians, and 4 Israelis. Some participants had already participated 2 years ago in a French workshop on the same theme at Megéve, France, organized by Simone Odiot from Pierre and Marie Curie University, Paris.

The goals of this ASI were to:

- Improve the understanding, on a fundamental basis, of the decomposition phenomena of energetic materials
- Apply this new developed understanding to:

  (1) Synthesize more powerful and less sensitive explosives at moderate prices to increase the effectiveness and decrease the vulnerability of systems containing explosives, (2) Control the decomposition velocity (burning rate) of propellants.

Generally, each speaker gave two lectures. The first lecture provided a snapshot of the state of the art through a survey of a technique, a review of the theory, or a description of an experimental technique. A second lecture reviewed the most recent results in the field of energetic materials.

(1) Fundamental Principles of Thermal Explosion, P. Gray, Gonville and Caius College, Cambridge, U.K.

(2) Introduction to Thermochemical Modeling, C. Melius, Sandia National Laboratories (SNL), Livermore, California

(3) Introduction to Tandem Mass Spectroscopy (MSMS) and Collision-Induced Dissociation Studies, J. Yinon, Weizmann Institute, Rehovoth, Israel

(4) Detonation Spectroscopy with Laboratory Scale Samples, N. Blais, Los Alamos National Laboratory (LANL), Los Alamos, New Mexico.

The principal results discussed at the workshop were the relationship between structure and properties of explosives and mechanisms and by-products of explosive decomposition. Results are summarized below.

Relationship Between Structure and Properties of Explosives

J. Alster, Army Research and Development Center (ARDEC), Dover, New Jersey, paid special attention to cyclic (cyclobutanes, azetidine derivatives). Some of their properties were measured, others were only estimated by calculations. New synthesis methods may allow economical production of compounds which until now have been considered exotic; e.g., aminoadamantane.

L. Politzer, University of New Orleans, Louisiana, by computational methods, attempted to determine the structure of molecules and to find relations between estimated or known properties (density, heat of formation) and measured sensitivities. Clearly, characterization of sensitivities constitutes a difficult problem: sensitivity is not well defined; it depends on numerous factors such as size, physical structure (defects, voids), methods of measurements, and nature of the observed phenomena. This ASI proposed some more precise definitions:

- Impact tests. Intensities about 1 GPa and duration between 100 to 200 microseconds
- Shock tests. Intensities of 20 GPa and duration of 0.05 to 2 microseconds
- Sensitivity. Corresponds to a threshold of shock initiation for a detonation
- Sensitivity. Corresponds to a threshold of initiation by an inflammation, violent combustion or other pyrotechnical event, or by a long-duration impact (few milliseconds)
- Explosiveness. Corresponds to the magnitude or the severity of the pyrotechnical event occurring after initiation by shock.

Theoretical Studies and Modeling of Decomposition

At the molecular level, the basis of theoretical studies is a calculation of potentials, energy levels, and bond energies. In the field of thermochemical data, S. Fliszar, University of Montreal, provided a method to evaluate, with good precision, the bond dissociation energies of energetic materials. Fliszar applied the X-alpha local spin density approximation to organic molecules, selecting an accurate value of the parameter alpha. Such evaluations provide a path that leads to thermodynamically allowed routes of the decomposition of an energetic

molecule, for which C. Melius, SNL, gave some examples by evaluating transition states.

D. Tsai, University of Maryland, Silver Spring, discussed an interesting theoretical molecular dynamics approach; a diatomic molecule A-B with quantized rotation, vibration, and electronic energy levels undergoes mechanical or thermal shock. What is the effect on the molecule? What is the time scale of transitions from a level to another? Transition times could be below a picosecond; it would be interesting to verify these calculations by experiments; e.g., a determination of relaxation times.

S. Odiot explained, with a three-dimensional molecular dynamics model, the possibility to observe in a monocrystal; e.g., nitromethane, an anisotropy in the velocity of detonation in the lattice. She demonstrated the importance of some chains, and the influence of quasi-alignments of groups or single atoms in the molecules and in the crystals.

Experimental Studies of Decomposition

Generally, the experimental technique consists of submitting an energetic material; e.g., HMX, RDX, TATB, TNT, to stimuli (shocks, heat, radiation) with longer or lesser durations, in static or dynamic conditions, under various pressures (high vacuum, atmosphere, high- or very high-pressure) and temperatures (from 4K to over 1,000K) sometimes after preshocking. The measurement techniques for decomposition products are generally optic or electronic (neutron scattering IR, photoelectronic or mass spectroscopy, MSMS). Some of the main discussions are summarized below.

- Fast Thermolysis, T. Brill, University of Delaware, Dover, heats a 1-to 2-mg sample at a rate between 50 and 800°K s^{-1} under a N_2 or Ar atmosphere at a pressure between vacuum and 7 MPa. Brill analyzes, by fast Fourier Transform Infrared Spectroscopy (FTIR), the gases that evolve in the heating process. Simultaneously, he continuously measures the temperature and the weight of the sample. Brill has analyzed the decomposition of nitrate salts, nitramines (HMX, methylene dinitramine) and other substances with N-NO_2 groups (Dinitroglycoluril [DNGU], 3Nitro1.2.4Triazol 5.One [NTO], azides). Brill can determine what are the conditions under which diffusion or chemistry control the decomposition. The limitations of this method are a slow resolution (20 ms) and some gases are not detected (N_2) or measured with difficulty (H_2O, HNCO).
- Properties at Very High Pressures, G. Piermarini, National Institute of Standards and Technology (NTIS), Gaithersburg, Maryland, studies the phase diagram, in the temperature-pressure plane, of RDX and HMX. The ruby fluorescence pressure sensor in his diamond anvil cell provides values each 3 or 4 seconds, and he obtains x-ray spectra through a window in the cell. The phase diagram (T versus P) for RDX and HMX was discussed at the ASI. The diagram for RDX shows that the gamma form is stable over 3.7 GPa and a beta form that is stable above 230°C. The alpha to beta transition is reversible, and the alpha form has an infrared band at 1000 cm^{-1} that disappears in the beta form.

Piermarini studied the pressure and temperature-dependent kinetics of decomposition of RDX and HMX, providing V* of activation, the sign of which determines the molecularity. Piermarini determined that the initial or the slowest decomposition mechanism is unimolecular for HMX, bimolecular for RDX. Piermarini also studied the behavior of nitromethane under high pressure and temperature: three decomposition routes are possible, depending on the pressure. In some circumstances above 3 GPa, it is possible to observe a decomposition that yields an amorphous carbon residue.

Decomposition Mechanisms of High Explosives by Kinetic Isotope Effect of Deuterium

S. Shackelford, U.S. Air Force Academy, Colorado Springs, exploits the isotope effect of deuterium to investigate decomposition of explosives that take place through combustion, thermal explosion, deflagration, or detonation by flying plates. Shackelford performs experiments with high explosives, pure or mixed with binders (propellants, PBXs). Shackelford's results are:

- HMX. The kinetics is governed by the rupture of the C-H bond, during combustion, in the solid state, in pure as well as in propellant formulations. In detonation, ruptures of C-H (solid) and C-N (liquid state) bonds are possible.
- RDX. In all cases (solid or liquid state), the rupture of C-H bond during combustion governs the kinetics.
- TATB. In combustion, the rate is controlled by the rupture of N-H in solid state, and possibly also in thermal explosions.
- TNT. In liquid decomposition or in a thermal explosion after initiation by shock, and perhaps in a detonation, the rate controling step is the rupture of a methyl-CH bond.

These results provide guidance on structure of the catalysts to be added, in order to modify the burning or detonating properties of energetic materials.

Detonation Products of Various Explosives

F. Volk, Institute of Chemical Technology of the Fraunhofer Gesellschaft, Karlsruhe, Federal Republic of

Germany, investigates the decomposition byproducts of HMX, RDX, TAGN, NQ, TATB, TNT, as well as binders, initiated at various temperatures, in a closed 1.5-m^3 vessel under vacuum or Ar atmosphere. With NQ, formation of HCN and NH_3, explains slower detonation velocities. Volk has also investigated the formation of diamonds in the soot.

Decomposition Reactions of Explosives 150 Nanoseconds after the Detonation Initiation

N. Blais and R. Greiner, LANL, investigated HNS, TNT, TATB (oxygen deficient), RDX, HMX, and PETN (more oxygen balances). They found C clusters in HNS detonation products, modeled the explosion with the KIVA code, and studied NO in the solid state ($< -161^{\circ}C$) demonstrating three decomposition reactions.

Dissociations of RDX and HMX Molecules by Collisions: Fragmentation Maps

J. Yinon, observed with MSMS, that for RDX decomposition results in simultaneous evolution of NO_2 and CH_2NNO_2; for HMX, CH_2NNO_2 evolves first and NO_2 evolves in a second step. Yinon studied numerous other molecules such as N-nitro or N-nitroso cyclic derivatives, nitroadamantanes, and polynitrobiphenyls.

Simultaneous Thermogravimetry and MSMS Investigation of Dissociation of RDX and HMX Molecules by Pyrolysis

R. Behrens, SNL, observes an induction period with HMX, obtains nitrosamines in the first step and a carbonaceous porous residue, probably with amidic functions. He also observes formation of water and dimethylnitrosamine in bubbles. With RDX, the process is more difficult: possible formation of hydroxy-s-triazine or s-triazine oxide. In his experiments, it seems that the behavior of RDX and HMX at the molecular level, under decomposition, is different, in spite of their very similar formulas.

XPS, UPS, and EPS (Photoelectron Spectroscopy, with Excitation by X-rays, Ultraviolet Rays, or Electron Beams) and Studies of Hot Spots and Sensitization Centers in Explosives

J. Sharma, Naval Surface Warfare Center, Silver Spring, Maryland, determined the nature of the products formed by a stimulus (shock) without ignition, but sufficient to sensitize these products, forming hot spots like fractures or holes with deposits on their inner surface. In TATB, dinitrofuroxan forms through loss of water, followed by dinitrofurazan by evolution of H_2; these two products are much more sensitive than TATB. Voids form in HMX with some liquid on the inner surface.

XPS, UPS, and EPS, can be performed with good resolution allowing verification of the quality of these products; e.g., TATB at 410 eV. In double-base propellants, the mesa effect could be explained by XPS studies of distribution of Pb (maximum Pb concentration ten microns under the burning surface).

Other Topics

S. Trevino, NTIS, determined the energy levels of torsion in the nitromethane molecule by neutron scattering at $4^{\circ}K$ on CH_3NO_2 and CD_3NO_2.

B.J. Van der Meer, TNO Prins Maurits Laboratory, Rijswijk, the Netherlands, used emission spectroscopy to detect decomposition products of laser-irradiated explosives. This method can be applied essentially to explosives containing metallic ions (primary explosives).

Conclusions

This ASI, chaired by S. Bulusu (Bulusu, 1990), ARDEC, was a success judged on the basis of the level of the scientific presentations, the quality of scientific exchanges, and the opening of opportunities to engage in common research programs. Based upon this ASI, the most fruitful lines of research that could be pursued in the near future are:

- Need to establish collaborative programs on theoretical research in molecular dynamics. Collaboration between groups in France and the U.S. is under exploration now.
- Application of the new-found knowledge on molecular structure of explosives to synthesize new substances with the desired properties. Some efforts in this area are already under way in France.
- Experimental research: (1) use of new femtosecond techniques to understand phenomena at molecular level; (2) choice of energetic polymers as materials for experimental studies; (3) experimental study of very highly sensitive products; e.g., HNF_2, HN_3, ClN_3, BrN_3, $N{\equiv}CN_3$, that can be initiated by weak stimuli such as freezing, heating, small pressure changes, and light. Weak stimuli can result in a detonation after very short distances. Molecular dynamics calculations in these simple molecules may provide insights on the physical foundations of their sensitivity.

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Sixth Scientific Assembly of the International Association of Geomagnetism and Aeronomy

by Dr. P.K. Chaturvedi, Space Plasma Branch, Plasma Physics Division, Naval Research Laboratory, Washington, D.C.

Introduction

The Sixth Scientific Assembly of the International Association of Geomagnetism and Aeronomy (IAGA) was held at the University of Exeter, Exeter, U.K., July 24-August 4, 1989. The IAGA scientific assemblies are held quadrennially; the last one was held in 1985 in Prague, Czechoslovakia. The IAGA also holds its meetings in conjunction with the general assemblies of the International Union of Geodesy and Geophysics (IUGG) of which it is a constituent member. The IUGG general assemblies are also held quadrennially--Vancouver, Canada, 1987, and Vienna, Austria, 1991. The IAGA is comprised of five divisions and several interdivisional commissions. Each division may have different working groups (see Table 1).

Table 1. IAGA Interdivisional Divisions

Division	Working Groups
1	Internal Magnetic Fields
2	Aeronomic Phenomena
3	Magnetospheric Phenomena
4	Solar Wind, Interplanetary Magnetic Field
5	Observatories, Instruments, Indices, Data

There are interdivisional commissions on Antarctic Research, History, Middle Atmosphere, External/Internal Geomagnetic Relations, and Developing Countries. All the divisions and commissions were represented in the meeting and all had organized general and specialized oral and poster sessions and workshops.

There were five union lectures, organized by each division, and there were several interdivisional specialized sessions. The oral sessions consisted of invited review and contributed presentations, while poster sessions were mostly contributed papers.

Ionospheric Fields and Waves

This 2-day session, organized under the auspices of Division 2 by Drs. J.-P. St.-Maurice, University of Ontario, London, Canada, and K. Schlegel, MPI for Aeronomie, Katlenburg-Lindau, Federal Republic of Germany (FRG). The session covered the physics of waves and fields in the earth's partially ionized upper atmospheric region known as the ionosphere. This region broadly covers the altitude range from 80-100 kms to several thousands of kms and is subdivided into regions known as the D-layer (less than 90 km), E-layer (90-150 km), and F-layer (higher than 150 km). The ionosphere has been studied for many decades both experimentally and theoretically, its importance stemming from its role as a near-earth ionization layer making radio frequency (RF) communications possible. The observational techniques employed to study the ionosphere have been the radio-wave probing (ionosonde technique), high-frequency electromagnetic (EM) wave scatter studies, magnetometer studies, scintillation of EM signals, and by *in situ* rocket- and satellite-borne probes. This has been an international effort with observations covering various longitudes and latitudes. There have been recent efforts to conduct controlled active experiments in the ionosphere; e.g., by releasing gas clouds from space vehicles and by ground-launched, high-power, high-frequency (HF) wave injections. The theoretical understanding of ionospheric dynamics and structures has also improved considerably--a dynamic region displaying motions and structures on many orders of magnitudes in scale both temporally and spatially. Session 2.9 was primarily devoted to small-scale phenomena and irregularities (in density, electric field, velocity) as compared with the general terrestrial scale sizes (~ thousands km). The session was divided into two oral sessions (mornings, July 29 and 31) and a poster session on July 31. The oral session on July 29 was primarily devoted to the high-latitude, E-region presentations, while contributions dealing with other topics constituted the other oral session. The poster session had a mix of both types of contributions. Post-assembly proceedings for presentations in this session will not be published.

High Latitude E-Region Presentations

A large effort in the high-latitude, E-region research (as also reflected in the IAGA session) has been concerned with the observations and theoretical understanding of the irregularities associated with the auroral electrojets. J. Providakes, Cornell University, summarized the interferometer technique used in probing the ionosphere by a high-frequency backscatter radar. The advantage of this technique is that better altitude resolution can be achieved. Providakes presented results taken

from Cornell's 50-MHz CUPRI radar that responds to 3-meter plasma irregularities in the ionosphere. The results on E-region (90-130 km) irregularities showed that Type III irregularities were presumably generated in the altitude range 105-110 km, rather than the top side altitudes as previously believed. (The *types* classification is based on the spectral shapes of backscatter returns.) There were also indications of narrow regions of enhanced temperature (*hot spots*) in this region.

E.C. Thomas, Leicester University, U.K., presented altitude measurements on meter scale irregularities taken with the Sweden and Britain Radio Aurora Experiment (SABRE) Altitude Determining Interferometer Radar Experiment at Wick, Scotland. The observations of *bright spots* (regions of enhanced backscatter intensity caused by irregularities) as a function of altitude were reported. The European Incoherent Scatter Radar Center at Trømso, Norway (EISCAT), was used to study the range and time resolution of these irregularities. K. Schlegel reported results on the altitude structure and time scales of these irregularities, especially such features as the duration of irregularities of various spectral form.

In a poster presentation, K. Schlegel presented spectral observations of short scale-size (16 cm) irregularities with large aspect angles (large angle of propagation with respect to the orthogonal direction to the magnetic field). M.V. Uspensky, Polar Geophysical Institute, Murmansk, U.S.S.R., described an auroral backscatter model of E-region irregularities and presented comparisons with the EISCAT observations regarding thickness of the scattering layer and the irregularity amplitude.

In poster presentations, M. Uspensky considered the effect of propagation of irregularities in the medium and compared results with the observations of irregularity drift velocity made with the HF radars. C. Haldoupis, MPIAe, Katlenburg-Lindau, FRG, presented results on the dependence of the backscattered power on the mean background density and strength of ambient electric fields. In a poster, he presented results on high-phase velocity, non-two-stream type irregularities which were possibly generated via a nonlinear generation mechanism. This study used data from EISCAT and Scandinavian Twin Auroral Radar Experiment (STARE) radars, which detect meter/scale irregularities and have common fields of view.

T. Robinson, Leicester University, presented a review of the recent theoretical work in the understanding of E-region plasma instabilities. He emphasized the nonlinear aspects of the well-known Hall current-driven, two-stream instability. This instability occurs when the equilibrium electron Hall drift exceeds the local ion-sound speed and excites plasma waves that have a phase velocity close to the ion-sound speed (irrespective of the electron drift speed), and have scalelengths in the range of several meters. Recent work has considered the effect of an enhanced electron collision frequency, ν^* (a function of wave amplitude) which is used to compute the saturation level of turbulence for the time stationary (nonlinearly stabilized) situation. This enhanced collision frequency is presumably caused by well-developed two-stream turbulence. A poster presentation by T. Robinson and F. Honary, Leicester University, considered this mechanism using kinetic equations and included the gradient-drift effects (caused by density inhomogeneity). They found that the saturation levels may be lower for this case.

J.P. Villain, National Center for Scientific Research, Orleans, France, reported observations of ion-acoustic waves from the HF backscatter radars in North America (Goose Bay and SHERPA radars), which supported the possibility of parallel currents contributing to the generation of the high-latitude, E-region, electrojet irregularities. F. Primdahl, Danish Space Research Institute, Lyngby, presented a comprehensive review of the *in situ* rocket measurements at various latitudes. These included the earlier results on the equatorial electrojet of S. Prakash, Physical Research Laboratory, Ahmedabad, India, and coworkers from Thumba, India, in the late 1960s to the recent CONDOR Campaign (1983) from Brazil which used coordinated multiple experimental studies of the equatorial electrojet. This review also included rocket studies of the high-latitude E-region.

R. Pfaff, Goddard Space Flight Center, Greenbelt, Maryland, reported preliminary results from the data obtained by a rocket launched from Esrange, Sweden, in 1989 for E-region studies. These included an observation that often the phase velocity of E-region, type-I-like (two-stream type) irregularities was smaller than the cross-field electron Hall drift (v_d). The turbulence of the E-region at high latitudes is often accompanied by enhanced electron temperatures (in contrast to the low latitudes). J.-P. St.-Maurice reported observations taken by the EISCAT radar that indicate ion temperature enhancements in addition to electron temperature increases in association with the turbulence. H. Opgenoorth, Swedish Institute of Space, Uppsala, reported observations of large electric fields and associated strong plasma turbulence and elevated E-region electron temperatures from an experimental campaign involving the EISCAT and CUPRI radars.

General

The other oral and poster sessions were a potpourri of various contributions dealing with wave phenomena in the ionosphere at various latitudes and altitudes.

S. Fukao, Kyoto University, Japan, presented nighttime, mid-latitude, E-region measurements of meter-scale size irregularities made with the university's 50-MHz radar.

The presentation by A.S. Rodger, British Antarctic Survey, Cambridge, was on F-region irregularities (rather than the E-region work emphasized thus far). Using data from the Millstone Hill incoherent scatter radar, DE-2 satellite *in situ* observations and ground-based scintillation measurements of plasma density irregularities at midlatitudes, various possible generation mechanisms for several classes of observed irregularities were discussed (such as the gradient-drift, current-convective, temperature-gradient-drift instabilities).

M. Pinnock, British Antarctic Survey, Cambridge, presented the results on decameter scale-size ionospheric irregularities obtained during the experimental campaign known as Polar Anglo-American Conjugate Experiments in which two HF radars at Goose Bay, Labrador (Canada) and Halley Bay (Antarctica) are used to conduct conjugate studies of the high-latitude ionosphere. The various observations were surveyed and mechanisms responsible for irregularity generation (such as the current-convective instability) and its dynamics (convection) were discussed.

H. Kohl, Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, presented results on artificially excited Langmuir waves in the ionosphere by the MPIAe-Heater Facility at Trømso, Norway. These waves were excited at F-region altitudes by shining a powerful HF beam and observations, using EISCAT radar, indicate the excitation of low-frequency, ion sound waves also.

R.E. Horita, University of Victoria, Vancouver, Canada, presented results on proton cyclotron echoes above the electron Langmuir frequency made with the Allouette (Canada) and ISIS-2 satellites at altitudes of 2,000-2,500 km.

P.L. Pritchett, UCLA, presented numerical simulation results on the modeling of Whistler wave generation by electron beams in the ionosphere during the Spacelab-2 experiments.

The remaining contributions were presented as posters. Some of these have already been reviewed in the sections above.

G. Ganguli, Science Applications International Corporation, McLean, Virginia, presented theoretical work on the possible plasma instabilities in the presence of a transverse sheared flow and a parallel current for a collisional medium and applied the results to the low-altitude ionosphere.

P.K. Chaturvedi and S.L. Ossakow, Naval Research Laboratory, Washington, D.C., presented theoretical results on the pump wave threshold requirements for possible externally controlled excitation (or suppression) of plasma instabilities in the E- and F-regions of the ionosphere by an HF pump wave (launched from the ground).

C.A. Chang, University of Western Ontario, London, Canada, and coworkers presented theoretical work on the possible excitation of the electrostatic ion-cyclotron instability by parallel currents (carried by electron beams) in a collisional medium. They concluded that currents on the order of 1,000 $\mu A/m^2$ would be required for the instability, and the instability was likely to be favored near the Harang discontinuity.

P. Rothwell, University of Sussex, Brighton, U.K., presented results on observations of narrow electron density layers and enhanced optical emissions in the E-region, based on data obtained from EISCAT radar and optical (TV camera) observations.

Summary

Experimental facilities such as the EISCAT, SABRE, STARE radars, and the MPIAe Heater facility (in conjunction with other facilities such as the CUPRI radar) are providing a rich database on the physical processes occurring in the low-altitude ionosphere. In addition, theoretical studies are resulting in an enhanced understanding of the region.

Acknowledgment

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The Sixth International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits

by Dr. Mario G. Ancona, Research Physicist, Electronics Science and Technology Division, Naval Research Laboratory, Washington, D.C.

Introduction

The biennial Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits (NASECODE) is one of the few world-wide scientific meetings devoted entirely to the numerical analysis of semiconductor devices, circuits, and processing. The conference was founded by Professor John J.H. Miller, head of the Numerical Analysis Group, Trinity College, Dublin, Ireland, and he continues to organize and run it. This report concerns NASECODE VI which was held on July 11-14, 1989, at the usual site of Trinity College[1]. The meeting featured 10 invited papers and 67 contributed papers and organized into 7 regular sessions and 7 special minisymposia. Roughly 40 percent of the contributions were from Western Europe, 25 percent from the U.S., 25 percent from Japan, and the remainder from the U.S.S.R., Eastern Europe, and Israel. In addition to these papers, a parallel Software Forum (13 presentations on simulation software packages) and Software Exhibition (9 software demonstrations) plus a Short Course on Software Tools for Process, Device, and Circuit Modeling were held, with the latter occurring before the conference on July 10. The proceedings of the conference ($75, softcover) and the short course lecture notes ($45, softcover) are available from Boole Press Limited, P.O. Box 5, County Dun Laoghaire, Dublin, Ireland.

The majority of the papers concerned semiconductor device modeling (rather than circuit or process analysis). Because of this emphasis and because of my own research interests, this report will discuss only device simulation work. A wide variety of approaches and applications in device modeling were presented, and I focus here on papers from five distinct areas which seemed to me of the greatest significance.

Three-Dimensional Device Simulation

One topic that received considerable attention at NASECODE VI was the development of efficient codes for the simulation of semiconductor (generally silicon) devices in three-space dimensions. Efforts to this end are ongoing at several laboratories around the world with the common aim to develop a user-friendly device simulation tool with broad applicability to many different device types. Several such codes were reported on at the conference all of which solve the standard fully coupled diffusion-drift, and electrostatic partial differential equations describing electron, and hole transport in both steady-state and transient situations. For flexibility in dealing with device geometry, the best programs use the finite element method, applying it on an adaptive Delauney tessellation (Voronoi polyhedra) of the three-dimensional (3-D) device region. Finite-difference approaches are also being pursued. The well-known Scharfetter-Gummel discretization is generally used, and the resulting algebraic equations are then solved. Obviously, the primary difficulties in 3-D calculations are associated with the computational load and with memory requirements, and it is thus imperative that numerical techniques be used that are efficient on large systems. Iterative methods are clearly indicated, and the method of choice appears to be some variation of the incomplete Cholesky conjugate-gradient technique with preconditioning. To speed convergence, some codes also employ so-called correction transformations in which one set of variables (usually the Slotboom variables) is used for the linearization of the nonlinear system while a second set is used in the actual iterative solution. Vectorizing and parallelizing such codes to gain more efficiency when used on appropriate computers is receiving attention as well. Finally, a critical issue in the 3-D device simulation efforts is the graphical presentation of results. This seemed to me a weak point of most of the presentations, and it is clear that much work remains to be done along these lines.

The 3-D simulator development efforts described at the conference were from IBM, Essex Junction, under Edward Buturla; at Keio University, Japan, under K. Hane; and a European Strategic Programme for Research and Development in Information Technologies (ESPRIT) project involving 10 universities and companies from across Europe under C. Greenough, Rutherford Appleton Laboratories, Chilton, U.K. Several Japanese companies (Matsushita, NEC, and Fujitsu) also described work in this area. At present (to my knowledge), none of these programs is available to outside users. A previous version of the IBM code Fielday I, has recently become available commercially in the U.S. (for

[1]The next conference is to be held at Copper Mountain, Colorado, on April 8-12, 1991.

further information, contact Dr. Buturla), and the distribution of the ESPRIT code is under discussion (likely just within the European Economic Community).

Numerical Techniques

A broad range of numerical techniques for analyzing the semiconductor transport equations was discussed at NASECODE VI. Among these were conjugate-gradient techniques (see page 46), multi-grid methods, spectral methods, operator splitting, waveform relaxation (WR), and lattice-gas methods. In addition, several papers re-examined the question of how best to generalize Scharfetter-Gummel to more than one dimension.

The idea behind multigrid methods is that by performing some iterations on a coarse grid and others on a fine grid, one can successfully reduce errors with both low- and high-spatial frequencies, thereby increasing the overall rate of convergence. Several papers presented implementations of this technique for the semiconductor equations. The results appear to be inconclusive in that (at least for the applications discussed) the overhead of the method generally outweighed any improvement in convergence rate. In a somewhat different usage of this method, Peter Blakey, Microelectronics and Computer Technology Corporation (MCC), Austin, Texas, reported on an efficient Poisson solver based on a single-level, multigrid technique (wherein the coarse grid corrections are done directly on the fine grid thereby decreasing overhead) which was used in their device simulation code BETTSI.

V. Axelrad, Technical University, Munich, Federal Republic of Germany, presented a paper on using a spectral (Fourier expansion) method for solving the diffusion-drift PDEs. Applications to one and two dimensions were reported, and impressive convergence speedups were demonstrated. However, it was unclear whether similar results would be obtained for a broad spectrum of semiconductor device problems. In particular the well-known flaw of spectral approaches, their inefficiency when solutions vary strongly, were not addressed in this presentation. Nevertheless, it may be that, as in other areas of application of spectral techniques, this theoretical disadvantage will not prove a severe drawback in practice.

A novel approach to device simulation was presented by Jacob White, MIT, Cambridge, Massachusetts, in which the WR technique of circuit analysis (for ODES) was applied to the device equations (PDE). In an application to metal oxide semiconductor field-effect transistor (MOSFET) simulation, good results were obtained even in high-current, strongly coupled regimes. Apparently, that the prime interaction between nodes is through the time-independent Poisson equation allows convergence to occur. (As yet, White has been unable to prove anything about the method.) The simulation time for the WR algorithm using a single time step for all nodes was comparable to that obtained using a conventional SOR. White expects (not shown) that, when the fact that in WR each node can be integrated with a different timestep is exploited, the method will become significantly more efficient than SOR. Moreover, as in circuit simulation, that the WR technique is naturally parallel means that it may have a future as parallel computers become more widespread.

Finally, in a late-news paper, I discussed efforts at the Naval Research Laboratory, Washington, D.C., to use lattice-gas (or cellular automata) techniques, previously developed in computational fluid dynamics for device simulation. The technique essentially buys increased parallelism and programming simplicity at the expense of more calculations, a tradeoff that can become favorable if one's computer is sufficiently parallel. I focused on the development of the lattice-gas model; i.e., the set of rules governing the cellular automaton, appropriate for solving the diffusion-drift partial differential equations. Some simulations results for a MOSFET obtained on the massively parallel Connection Machine were presented; however, whether this approach will prove practical remains an open question.

Transient Problems

In transient simulation, one interesting presentation was a review by Peter Blakey. This paper summarized MCC's work over the last several years on time-domain simulation of micro- and millimeter-wave transistors as incorporated in their device simulator BETTSI. Most of the work has been published, and the talk was of value primarily because (a) unlike most of the conference, this work concerned high-frequency devices, and (b) it included opinions and evaluations of various numerical approaches based on their extensive simulation experience. They employ a decoupled method; i.e., one in which electrostatics and transport are uncoupled within each timestep, since it is more efficient than the fully coupled approach when small timesteps are used (here required for studying high-frequency phenomena). In addition, it is worth noting that they do not use the ubiquitous Scharfetter-Gummel discretization in keeping with the conclusion of Kreskovsky that Scharfetter-Gummel is just one technique for adding in artificial diffusion to stabilize the numerical scheme.

P.A. Gough, Philips Research Laboratory, Redhill, U.K., presented a paper on inductive switching. This talk was noteworthy both for the clear identification of the important features involved in the switching and for the excellent graphical presentation of the results.

Although the conference concerned primarily numerical approaches to device simulation, several contribu-

tions discussed problems in which analytical techniques formed an important part. Perhaps most notable was an invited paper presented by Michael Ward, Stanford University, Palo Alto, California, that provided an elegant asymptotic analysis of the multiple steady-state solutions possible in pnpn structures. These solutions underlie the well-known transient latchup phenomenon occurring in such structures, an effect which can be both useful; e.g., in thyristors, and a parasitic; e.g., alpha particle-induced latchup in complementary metal oxide semiconductor devices. The problem is severely ill conditioned and has been solved numerically only with much effort. Ward's analysis bypasses all of the numerical difficulties via a semianalytical approach based on depletion layer assumptions (connection conditions) like those used in the elementary analysis of a p-n junction plus a simplified treatment of base width modulation (Early effect). Not only is this a neat dissection of the problem, but it also provides a clear picture of the essential features of latchup.

Monte Carlo Simulation

In the area of Monte Carlo simulation, it seemed to me that little new ground was broken at NASECODE VI. Among the topics discussed were weighted Monte Carlo approaches, path-integral Monte-Carlo, and simulations of various devices including avalanche photodiodes, high-electron mobility transistors, metal Schottky field-effect transistors, and quasi-one-dimensional structures.

Perhaps the most interesting of the presentations was one given by Michael Littlejohn, North Carolina State University, Raleigh, (first author: J. Pelouard, CNRS, Bagneux, France) in which Monte Carlo solutions were used to investigate simplified descriptions of nearly ballistic transport in III-V semiconductors. In particular, transport in one-dimensional, planar-doped barrier structures and heterojunction bipolar transistors were studied. To form the simplified description on the basis of Monte Carlo simulation, they split the electron gas into three constituent gases: ballistic, quasi-ballistic, and velocity relaxed (drifted Maxwellian). These categories represent electrons that have suffered zero, one-to-three, or greater-than-three anisotropic collisions, respectively. (The Monte Carlo simulations show that three anisotropic collisions cause a remarkably sharp transfer of electrons from the ballistic population to the Maxwellian.) Then, employing this three-fluid model in device simulation, they obtain excellent agreement with full Monte Carlo solutions. Needless to say, one can question the robustness of this type of approach; however, its success here suggests that there is a place for simple models in the study of highly nonequilibrium situations.

Future of Semiconductor Device Simulation

Jeffrey Frey, University of Maryland, Silver Spring, presented an invited talk entitled "Device Simulation for the New Century." This presentation, while clearly being one person's view, did emphasize an important underlying theme of NASECODE VI: the health of the microelectronics enterprise worldwide is becoming increasingly dependent on simulation capabilities. This trend is fueled, of course, by the continual reductions in the spatial and temporal scales of state-of-the-art devices. As devices (and circuits) become smaller, faster, and increasingly complex, intuition and trial-and-error are less and less useful for guiding technological development. Moreover, the new devices and circuits are not only more complicated but may involve new physical phenomena such as quantum effects. Exploiting these phenomena and perhaps developing new device operating principles will depend on our modeling and simulation capabilities. Finally, there is the need to migrate research simulation tools to the engineering environment; e.g., running on workstations in an interactive mode with readily understood graphics. All of these areas represent major challenges for device, circuit, and process modelers; the extent to which they are met can be expected to have major impact on future growth in microelectronics.

NEWS, NOTES, AND ABSTRACTS

Semiconductor Growth and Processing in the U.K.

by Dean L. Mitchell, the Liaison Scientist for Solid-State Physics in Europe and the Middle East for the Office of Naval Research European Office.

The Semiconductor Committee of the Science and Engineering Research Council (SERC) in the U.K. held a 1-day workshop on "Growth and Processing" at the Royal Society in London on January 15, 1990. The purpose of the workshop was to identify materials and materials-related issues which are likely to have impact on SERC-supported research during the next 5 years. The comments and recommendations of participants at the workshop were solicited by the committee to help them formulate research priorities and funding projections for SERC-supported research. Attendance was limited to fewer than 100 attendees. There were 60-70 from the university sector with the remainder from industrial and governmental sectors.

The Semiconductor Committee was formed last year as one of the topical components of the newly formed Materials Science and Engineering Council (MSEC). The MSEC was formed in order to draw together the various materials-related programs in the science and engineering councils. The intent was to improve coordination of materials research and to give materials greater visibility in the SERC. The current chairman of the MSEC is Calvin Humphries, Cambridge University. Roger Heckingbottom, British Telecom, chairs the Semiconductor Committee.

The research budget, which falls within the purview of the Semiconductor Committee, totals £800,000/year compared to a total budget of £9,250,000/year for semiconductor-related research funded by all elements of the SERC. The predominant proportion of this total funding is in directed research. The directed research areas include: the Research Initiative (RI) in Low-Dimensional Structures overseen by the Physics Board (£3,750,000/year) and the RI in Low-Dimensional Devices overseen by the Engineering Board (£1,750,000/year); the Interdisciplinary Research Center at Imperial College, London (£1,650,000/year); and, the LINK program which is funded jointly with the Department of Trade and Industry (£1,650,000/year). The funding for unsolicited proposals in the "response" mode totals £1,100,000/year with £200,000/year under cognizance of the Physics Committee, £100,000/year under the Optical-Effects Subcommittee, and £800,000/year under the Semiconductor Committee.

In his introductory remarks, Heckingbottom introduced the four subfields that the committee considers in its purview:

1. Growth and processing
2. Properties and characterization
3. Surfaces and interfaces
4. Low-dimensional structures and devices (funded as RI; renewed for 4 years).

Of these, growth and characterization is being given special attention because of a perceived lack of coherency and collaborative interaction among the current research programs in the U.K. In later discussions, John Beeby commented that the success rate for proposals deemed supportable in this area was 1:7 in the last round of submissions. However, the proposals lacked excitement and innovation; hence, the organization of this workshop was to stimulate improved research.

The workshop was arranged by Peter LeComber, University of Dundee; assisted by Tony Stradling, Imperial College; and John Beeby, University of Leicester. The scheduled talks provided reviews of the current status of research in areas related to materials growth and processing. The talks were tutorial and covered the surface chemistry and growth kinetics for the epitaxial growth techniques currently in use by Bruce Joyce, Imperial College, and the purification of Metal Organic Chemical Vapor Deposition precursors by David Cole-Hamilton, St. Andrews University. Processing research was reviewed by Alan Webb, Plessey/Coswell, who compared the various etching techniques and their limitations; Ted Harris, Phillip's/Redhill, who gave a somewhat general tutorial on band structure engineering; and, John Cairns, University of Dundee, who reviewed aspects of packaging. Materials were covered by John Williams, University of Manchester, who reviewed the status of the group IV and iso-electronic III-V and II-VI semiconductors; Brian Wherret, Heriot-Watt University, who covered the special materials requirements for nonlinear optical applications; Peter LeComber, University of Dundee, who reviewed the status of amorphous silicon.

The talks were informative and gave an overview on current research capabilities in terms that nonspecialists;

i.e., those in adjacent fields, could appreciate. In the discussion that followed, Roger Heckingbottom was questioned closely on how he saw the future support for semiconductor research proceeding within the SERC. He also was questioned on how he intended to recommend the distribution of funds. On both counts, Heckingbottom was cautious but forthcoming. He pointed out that the expectation for increased funds is not realistic unless the community could generate innovative research initiatives that could draw funds away from other areas. With respect to funding of research subelements falling within the purview of the committee, he appeared to favor strengthening the Growth and Processing at the expense of other subelements; Surfaces and Interfaces is the most likely candidate for cuts.

There was a rather thorough discussion of the perceived failure of British suppliers to come up to international standards for GaAs substrates. Supplies from Japan are not reliable, with delays occurring at critical times. New projects funded under the LINK program were mentioned which may improve the situation for GaAs. However, no work on ternary substrates appears to be going on in the U.K.

The process by which the SERC probes the community and sets priorities for funding different disciplinary areas was very interesting to observe. As with the National Science Foundation in the U.S., the industrial and governmental researchers appeared to recognize and accept the near-monopoly that university investigators have in seeking support from the SERC. However, the allocation process is quite different from the U.S. Democracy prevails in workshops such as this, which provide advice to the SERC. The chairman, however, made it clear that he would decide on final recommendations to the SERC. These recommendations from the community generally have been followed by the SERC in the past; however, there is grumbling about a new IRC in low-dimensional semiconductors slated for Cambridge University that was awarded without competition. There are other signs, as well, that the SERC is taking more control and is guiding the community in directions that it chooses rather than operating in a response mode, as in the past.

Monitoring Lightning Hazards to Aircraft

by Hans Dolezalek, the Liaison Scientist for Ocean/Atmosphere in Europe and the Middle East for the Office of Naval Research European Office.

The increasing sensitivity and use of electric and electronic parts in aircraft, as well as the increasing use of composites in the aircraft skin, heightens the hazard from lightning. This hazard has gained a special significance for the cases of aircraft directly hit by lightning, triggered while flying nearby or through an electrified cloud. The triggering process may become significantly more dangerous when the aircraft's electrical system (instead of the metallic skin) represents a conductor inserted into the cloud's electric field. In addition, the surface charge on the nonmetallic skin may be larger than expected. The assumption (which requires verification) is that most aircraft-triggered lightning occurs in electrified clouds that have not developed into a thunderstorm with natural lightning. The basis of this assumption is:

- Lightning-producing clouds are more easily detected and therefore avoided
- Number of pre-thunderstorm clouds may be much larger than the number of fully developed thunderstorms
- Natural electric fields may be large enough to be enhanced by an aircraft to trigger lightning generation, while still insufficient to produce natural lightning.

In addition to the danger of a triggered lightning hit, aircraft with a nonmetallic skin may also be exposed to further risks in highly electrified clouds. For metallic aircraft, the hazard to sensitive internal electronics primarily originates from the magnetic field of nearby lightning strokes. In nonmetallic aircraft, the strong environmental electric fields may be enhanced by the electrical wiring to a degree that is destructive to electronic elements even if no lightning occurs.

The problem is that it is not easy to detect highly electrified clouds without lightning or sferics. The installation of fieldmeters on the ground to detect high electric fields would require an unrealistically dense network. The Physics Department of the University of Manchester, Institute of Science and Technology, developed a new method to solve this problem.

This method uses radar with a 300-km diameter coverage along with a sophisticated application of the polarimetric properties of the radar. Several parameters are calculated from the radar data, which allow the derivation of size, form, direction, and nature of the particles in a cloud (raindrops, snowflakes, graupel, and ice crystals). This information, in turn, allows estimations of the location and magnitude of strong electric fields.

This result is one fruit of the collaboration between various groups in the Physics Department, supported by the U.S. Air Force Office of Scientific Research, the National Environmental Research Council (U.K.), and the U.K. Meteorological Office. This research was undertaken with a much larger goal than just the detection of dangerous clouds (Frost, et al., 1989).

References

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Seventh International Meeting on Ferroelectricity

by Larry L. Boyer, Clive A. Randall, and Wallace A. Smith. Dr. Boyer is with the Condensed Matter Physics Branch, Naval Research Laboratory, Washington, D.C.; Dr. Randall is with the Materials Research Laboratory, Pennsylvania State University; and Dr. Smith is with the Materials Division, Office of Naval Research, Arlington, Virginia.

Introduction

The Seventh International Meeting on Ferroelectricity (IMF) was held in Saarbrücken, Federal Republic of Germany (FRG), from August 28-September 1, 1989. More than 400 participants came from 28 countries. Particularly noticeable was the large contingent of Japanese participants that was second only to the number of participants from the host country. Substantial representation from Eastern European countries reflected their new freedom to travel. The Soviet delegation, which ranked fourth in size following Germany, Japan, and France, included several students--another sign of changing times.

Thirty-one invited talks provided an overview of mature research areas and highlighted emerging topics, while the bulk of the research progress was presented in more than 450 poster papers. The reliance on posters helped communication across language barriers. At a meeting this size, a single participant can absorb at most, 10 percent of the information presented; fortunately, a comprehensive conference proceedings will soon appear in the journal *Ferroelectrics*. In this overview, we shall highlight some of the most significant results that came into our view.

Presentations

In an invited talk, Weyrich, Saarbrücken, presented a convincing case that first principles calculations can be effectively employed to calculate the elastic properties of ferroelectric materials. Weyrich began with a discussion of density functional theory, which provides the basic theoretical foundation for such calculations. In this approach, the charge density is determined self-consistently by solving a one-electron Schrödinger equation in which exchange and correlation are included through a local density approximation. The resultant charge density is then used to determine the electronic ground state energy. Within the past 10 years, this approach has been applied to compute material properties of a wide variety of materials with generally great success. However, relatively little has been done with this approach for ferroelectric materials, partly because of their complex crystal structures and partly because of difficulties arising from the macroscopic electric field. The only rigorous way for treating the latter problem would be to perform the calculation for a system of finite size in one dimension. Weyrich uses a linearized muffin-tin orbital basis in a bulk calculation of total energies for $BaTiO_3$. By computing the change in energy as a function of specific structural distortions, in a so-called "frozen-phonon calculation," he obtains reasonably accurate results for elastic properties. And, most encouragingly, he obtains the correct volume dependence of the energy difference between the cubic structure and the ferroelectrically distorted ground state. First principles calculations are needed for a clearer understanding of the mechanism involved in ferroelectric transitions. In addition, since they do not rely on experimental input, genuine predictions are possible. The possibility of surveying the properties of new materials families on a computer provides an exciting new opportunity for materials research.

While the area of high-temperature superconductivity is only indirectly germane to the conference as a whole, it nonetheless formed the subject of one of the plenary sessions and of a substantial poster session. The plenary session consisted of two reviews: one by Weber of the Institut für Physik at Dortmund and one by Müller of IBM Zürich, the codiscoverer of high T_c oxides. Weber's talk provided an excellent overview of the basic theoretical concepts with emphasis on the possible electronic mechanisms. These range from very exotic fractional quantization ideas to straight-forward approaches in which the electron pairing stems from virtual electronic excitations instead of virtual phonons. The most significant impression is the lack of a clear consensus among those favoring nonphonon mechanisms. By contrast, Müller's talk emphasized the connection between ferroelectricity and superconductivity and the connection of the former to the presence of *double-well* potentials for the ionic motions in the perovskites. He discussed his own past work in this area and then proceeded to emphasize some recent work, which suggests a corresponding connection between *double-well* motion and high-T_c superconductivity. Müller also cited the characteristics of the electronic structure of both systems; e.g., nearly full d shells, which may impart a unique *softness* to the electronic structure, further enhancing the influence of lattice motion.

An important theme at this meeting was the appearance of order/disorder characteristics in displacive ferroelectrics traditionally described in terms of a soft mode. Most notable were two reports, by Nelmes et al., and Fontana, et al., of an order/disorder contribution to the phase transition of $PbTiO_3$ which is typically regarded as a classic soft-mode displacive ferroelectric. Moreover, three invited speakers--Schmidt, Burns, and Müller--referenced the 1968 diffuse x-ray scattering studies of Comes, Lambert, and Guinier in which an order/disorder component was found in $BaTiO_3$ and $KNbO_3$. As renewed interest causes more sophisticated characterization methods to be used, the relationship of order/disorder and displacive descriptions of ferroelectrics will be a topic of vigorous debate at future meetings.

Glassy or relaxor ferroelectrics was the focus of much attention in ferroelectric systems ranging from perovskites to alkali/halide cyanides. In these systems, there is general agreement that an incoherent lattice frustrates the long-range dipolar cooperative interactions and creates localized polar clusters. Burns, IBM Yorktown Heights, presented experimental differences between glassy and normal ferroelectrics in the respective temperature dependencies of optical index, thermal expansion, and specific heat. There were several papers from Poland, Japan, and the U.S.S.R. reporting research on cation order/disorder in lead perovskites, including $Pb(In_{1/2}Nb_{1/2})O_3$, $Pb(Sc_{1/2}Nb_{1/2})O_3$, $Pb(In_{1/2}Ta_{1/2})O_3$, and $Pb(Sc_{1/2}Ta_{1/2})O_3$, where thermal processing allows manipulation of the long-range cation order and hence changes between normal and glassy ferroelectric states. Despite the number of papers, there still remains a controversy over whether the polar microregions in glassy ferroelectrics are static or dynamic.

Domains and domain walls continue to be an important area of ferroelectric studies. Amelinckx, Antwerp, described state-of-the-art transmission electron microscopy techniques for the characterization of domain types and domain wall structures. Special attention was given to the development of discommensuration structures in incommensurate ferroelectrics and ferroelastics. Ishibawa took a theoretical perspective and applied Landau-Ginzburg theory to demonstrate how the order parameter varies across a domain wall. The spatial variation of the order parameter, the wall energy, and the activation energy differ dramatically among different ferroelectrics. Arlt, Aachen, FRG, presented an up-to-date account of a stress model which relates domain configurations to the differences in dielectric and piezoelectric properties in coarse- and fine-grained $BaTiO_3$ ceramics.

From the applications perspective, Cross, Penn State, presented a masterful overview of the whole range of topics from ferroelectric thin films in microelectronic circuits to piezocomposite sonar sensors covering the surface of a submarine. In each application, the details of the basic ferroelectric materials properties were tied to the performance of practical devices. One imaginative direction that Cross highlighted was the potential for forming micron-scale motors, and hence robots, using piezoelectric motors. While the precise use of these micro motors is not clear, this possibility struck the imagination of quite a number of participants; we shall surely hear more in the years to come.

Geideman, McDonnell Douglas, drew considerable attention to nonvolatile semiconductor, random access memories. The talk described the device architectures of bistable capacitor memories based on the PLZT family of ferroelectrics, including both the research issues in incorporating ferroelectric films into semiconductor processing as well as the potential performance of the devices. Geideman confidently predicted 64- and 256-K nonvolatile RAMs by the time of the Eighth IMF in 1993. Details of ferroelectric film synthesis appeared in poster papers on sol gel synthesis of ferroelectric films by several research teams: Arizona State/McDonnell Douglas, UCLA, and Battelle/Penn State. A coordinate set of three posters from China surveyed all the major film deposition approaches and presented preliminary results on ion beam sputtered films. This topic is destined to become a major theme at future ferroelectrics meetings.

In an invited paper, Whatmore, Plessey (with a poster from the same laboratory) provided details on infrared imaging based on thermal detectors. A thorough analysis of device requirements was coupled with ingenious materials engineering to produce two-dimensional arrays incorporating lead scandium tantalate. Good quality thermal images were shown from a 100 x 100 array operating at room temperature. Quadrupling the pixel count was projected as feasible with present materials and device technology. Infrared sensors is a mature area for the application of ferroelectrics, but papers such as these show that significant improvements can be made by carefully engineering material properties to device needs.

The meeting ended on an upbeat note for the U.S. ferroelectrics community as they received the call from the International Committee to host the Eighth International Meeting on Ferroelectricity in 1993 at the National Institute of Standards and Technology, Gaithersburg, Maryland. Much hard work will be required to meet the high standard set by the organizers of this Seventh IMF in Saarbrücken.

Second International Conference on Vacuum Microelectronics

by A.K. Ganguly and R.K. Parker, Naval Research Laboratory, Washington, D.C.

Introduction

The Second International Conference on Vacuum Microelectronics was held at Bath, U.K., July 24-26, 1989. The purpose of the meeting was to address the basic physics, concepts, fabrication, and applications of all aspects of vacuum microelectronics science and technology. The meeting attracted 150 participants from 12 different countries, and 62 papers were presented. The meeting brought together the solid-state and vacuum scientists in this new field where the two disciplines overlap and complement each other. The scientific program consisted of eight oral sessions and one poster session. The sessions represented a variety of topics such as fabrication and characterization of field emitter arrays, electron sources, transport in solids, diagnostic techniques, and devices. No new breakthroughs in technology were reported, but very significant and impressive advances in

the existing technologies were achieved. Some of these achievements are highlighted below.

Field Emitter Arrays and Devices

The field of vacuum microelectronics is centered on the exploitation of microminiaturized electron emitters. Although a wide range of emitter technologies are under study, much of the recent attention has focused on the field emission array (FEA), which combines solid-state processing and fabrication with the advantage of vacuum as a medium for ballistic transport of electrons. The FEAs are interesting as potential sources for vacuum electronic devices. The progress in the fabrication and characterization of the gridded field emission arrays reported in the conference was very impressive. The thrust of the fabrication techniques is to obtain stable, long-lived microtip arrays with uniform tip geometry, high packing density, and increased density. The basic research is concentrated on a complete understanding of the surface properties and the process of field emission in extremely high, nonuniform field.

New and significant contributions in this field were presented by researchers from GEC Hirst Research Centre, Wembly, U.K., Lawrence Livermore National Laboratory (LLNL), California; SRI International, Menlo Park California, Cornell University, Ithaca, New York; Siemens AG, Federal Republic of Germany; and the U.S.S.R. representatives. The GEC has the most comprehensive experimental and theoretical research programs in this field; it can produce semiconductor (Si) as well as metal (gold, niobium, and molybdenum) tip arrays. Wet etching was used for gridded Si tips (D.F. Howell, R.D. Groves, R.A. Lee, C. Patel, and H.A. Williams) and dry etching for metal tips (S.E. Jacobsen, N.A. Cade, and R.A. Lee). An experiment by Howell et al., with a 10x8 array of Si tips (spacing of 10 micron between adjacent tip) shows that the emitted current follows Fowler-Nordheim relation but the area of emission is much smaller than the area of the tips. The speculation is that the emission most probably occurs from microstructures formed on the surface. Although the current density is high ($\sim 10^7$ A/cm^2), the current is small ($\sim$ 100 nA per tip). The emission shows nonuniformity in the tips and many tips failed to emit. The energy distribution of the emitted electrons is very narrow ($\Delta E/E \approx 0.28\%$), and the emission occurs over a small angle ($\sim 6^o$). Both these properties are desirable for microwave device applications.

At Cornell University, N.C. McDonald is fabricating gated Si structures using the *double bird's peak* method. The structures appear uniform and the tip radius varies from 20-50 nm. He also fabricated large arrays of wedge-shaped Si field emitter cathodes. These structures have not yet been electrically tested but seem to be of excellent quality optically. The paper by D. Stephani and J. Eibe, Siemens AG, described the fabrication of densely packed ($2x10^7$/cm^2) and sharp (tip radius 10 nm) Si field emitter arrays by dry etching techniques. They were able to produce arrays with the ratio of tip height to tip spacing greater than unity. The structures are not gated but are very uniform. Electrical testing of the structures has yet to be performed. P.C. Allen, Thorn EMI, also reported fabrication of Si tips using both the multifaced samples with tip radius about 15 nm. Some tungsten field emitters were also fabricated with tip radius around 15 nm. J. Orvis, LLNL, presented an interesting paper on the fabricating and testing of miniature field emission diodes and triodes made out of Si. The talk indicated that the triode structure will soon be tested.

C. Spindt, SRI International, reported the recent advances made in the fabrication and characterization of metal field emitter arrays at SRI. They produce very uniform and high-quality metal tips with a packing density greater than $1.5x10^7$ tips/cm^2. The emission from an array of 200 tips produced an average current of 1 μA per tip at a gate voltage of 35 V and 10^{-9}T pressure. The lifetime is about 6 months at this pressure. The current increases to 40 μA per tip at a gate voltage of 75V. The average current density of the array is in the range of 100-1,000 A/cm^2. Operating with high anode voltage of 1kV and pulsed gate voltage (250V peak, 60 Hz), they obtained a large current of 500 μA/tip from a 12-tip array. Simple calculations show that stable emission occurs from $F^2 = 8\pi\gamma R^2$, where F = γ electric field, = surface tension and R = tip radius. Tips get dull if $F^2 < 8\pi\gamma R^2$ and build-up occurs if $F > 8\pi\gamma R^2$. They are also fabricating triodes. I. Brodie discussed noise analysis and fluctuation phenomena in field emission.

V.I. Makov, Moscow Physical Institute, talked about field emitter diodes. They measured I-V characteristics of a field emitter diode at pressures ranging from 10^{-5}-10^5Pa and observed very stable operation of diode. They also concluded that the diode can operate in a ballistic mode at a pressure of 10^5Pa. N.I. Sinitsyn, Academy of Sciences, Moscow, presented in detail the performance characteristics of the miniaturized microwave backward wave oscillators (BWOs) and klystrons developed in their laboratories. These devices use thermionic emission cathodes. The BWO operates in the frequency range of 36-260 GHz with input voltage varying from 400 to 1,800 V. The output power is between 10 and 40mW with an efficiency around 5 percent. The klystrons operate in the frequency range 50-150 MHz with an efficiency of 35-40 percent. Power output is 0.1 to 10 W.

A paper by Phillips, Gray, and Smith, NRL, discussed the feasibility of a field emitter array distributed amplifier operating in the 50-100-GHz frequency range. As pointed out by Anderson, Varian Associates, Palo Alto, California, the main difficulty of using the FEAs as triode elements is the low transconductance. The low transcon-

ductance is caused by the small effective area of emission mentioned earlier. The distributed amplifier configuration gives a higher value of transconductance. The experiment has not been performed.

Electron Sources

Other technologies of producing cold cathodes with high-current densities were discussed in several papers. G.G.P. Gorkom and A.M.E. Hoeberechts, Phillips Research Laboratories, the Netherlands, obtained high-current density (800 A/cm^2) from an Si cold cathode with a reverse biased pn junction parallel to its surface by fabricating a very thin and heavily doped n-type layer. Avalanche breakdown occurs under reverse bias and the electrons with energy higher than the vacuum level pass through the n-type layer into vacuum. T. Tsukamoto et al., Canon Research Center, Japan, fabricated a cold cathode based on avalanche breakdown in Schottky diode made with a 10-nm tungsten layer on p-type GaAs. The breakdown voltage is 5 V and the emitted current density is about 100A/cm^2. K. Yokoo et al., Tohoku University, Japan, developed tunneling emitter arrays with metal-insulator-semiconductor (MIS) structure. A field emission electron source controlled by a scanning tunneling microscope was demonstrated by M.A. McCord et al., IBM Research Center, New York.

Electron Transport in Solids and Tunneling

A few papers were devoted to the studies of the electron transport in high electric fields and tunneling through thin barriers. P.N. Cutler, Penn State University, University Park, presented a review of the progress in tunneling theory. Multidimensional models, including many body effects, are being developed for application to vacuum microelectronics. K.L. Jensen and F.A. Bout, NRL, developed a one-dimensional model by combining a particle trajectory description of quantum transport with a Monte Carlo analysis to simulate scattering and tunneling phenomena.

Conclusions

The high-current density and the low transit time of the field emitter arrays make these structures excellent sources of electrons for application in a wide variety of devices such as fast switching, flat panel display, high-brightness cathode, high-frequency triodes, wide-band and high-frequency distributed amplifiers. The development of these devices, of course, depends on the successful fabricating and processing of the FEAs with uniformity, reliability, long life, and large current density. The FEA vacuum microelectronics is still in its infancy. The rapidly evolving capabilities for microfabrication of structures and the improved microscopy needed to resolve the events at the tip of the emitter may provide the opportunity to exploit successfully the long-sought potential of field emission.

Magnetic Resonance in Many Disciplines

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Introduction

Magnetic resonance, a phenomenon discovered only 45 years ago, has spawned so many subfields that its practitioners are able to communicate only with great difficulty across its boundaries. Magnetic resonance imaging (MRI) now familiar to much of the general public, persuades 80-kg samples to slide willingly into a magnet of 1-m bore; for other workers, the sample is a precious few milligrams dispersed throughout a 5-mm sample tube. Still others spin solid samples at 15kHz (0.9x10^6 rpm). There are several excellent scientific meetings devoted to various aspects of magnetic resonance and its applications. The International Society of Magnetic Resonance (ISMAR) has recognized and welcomed such diversity over its 20-year history and specifically constructed a scientific program that brings together all the major strains of magnetic resonance. In general, it succeeds.

The 10th meeting of ISMAR was held in Morzine, France, July 16-21, 1989. Morzine, in the French Alps, is about 100 km from Geneva. Morzine appears to be seeking out conference trade and the townspeople and businesses were especially helpful to the conferees. The proceedings of the conference will appear in the *Bulletin of Magnetic Resonance*.

Topics Presented

Multidimensional Nuclear Magnetic Resonance and Biological Molecules. Two-dimensional (2-D) multidimensional nuclear magnetic resonance (NMR) has become a common, if not familiar, technique in almost all NMR laboratories. Richard R. Ernst, Eidgenossische Technische Hochshule (ETH), Zurich, is one of the founders of multidimensional Fourier transform techniques. In these experiments, one has substantial control over the internal Hamiltonian governing the evolution of the spin system. One may separately turn on or off short-range magnetic couplings, long-range couplings, chemical shifts, and heteronuclear couplings. Three-dimensional (3-D) NMR seems a useful extension, but data handling requirements are daunting; a 1K x 1K x 1K data set requires 1 gigawords of storage. However, computer hardware has improved so rapidly that some of the experiments, proposed but infeasible some years ago, are now possible. Ernst examined the most useful combinations of 3-D NMR experiments and indicated where he felt one could gain new information and where one only looked at old (gained just from 2-D NMR) information, but in a systematic way. These issues are somewhat reminiscent of the debate 10 years ago as to whether 2-D NMR really contained more information or was just a systematic way to do a series of one-dimensional (1-D)

experiments. The result is that 2-D has more information than 1-D; and 3-D NMR, in the right hands, can give more than 2-D.

The utility of 3-D NMR was reinforced by Robert Kaptein, Utrecht University. He made the practical point that 3-D NMR increases spectral resolution--a peak that is unresolvable in 2-D may be resolved in 3-D. Indeed, one of the limitations of the extension of multidimensional NMR to larger biomolecules is the overlap of peaks, overlap that is partially reduced at higher magnetic field. There is something elegant about increasing spectral resolution by creating a better experiment, rather than racing to ever higher magnetic field. Of course, the solution will be to do both the clever experiment and buy the bigger machine.

As in any spectroscopy, interpretation is the key. Interpretation problems are highlighted in 2-D (and higher) NMR because the number of peaks is of the order of hundreds to thousands, depending on the complexity of the molecule. Algorithms and protocols for peak assignments have developed over the years. One wishes to automate this procedure and proceed more directly from the spectra to the chemical structure and eventually to secondary and tertiary physical structure. Geoffrey Bodenhausen, University of Lausanne, reported about progress on automated structure determination. The approach is to examine each multiplet in the 2-D spectrum and then determine all the spin topologies consistent with that multiplet. Analysis leads to a degenerate family of chemical fragments consistent with the multiplet. One then rationalizes the entire chemical structure by requiring that the fragments be consistent with one another. This procedure is shown to work for very small spin systems.

Kurt Wüthrich, ETH, has taken 2-D NMR as far as anyone in establishing and executing protocols for protein structure determinations. He indicates that present techniques serve for the 3-D structural determination for proteins with molecular weights up to about 15,000. Such analyses are quite formidable and extension to proteins an order of magnitude larger does not seem feasible, in my opinion. Unless there is a breakthrough in automated analysis, it appears that the impact of NMR analysis on proteins will be the detailed understanding of how a few proteins are put together, rather than a routine method for determining the full 3-D structure of all proteins of interest.

Structure determination is also just one step in understanding the functioning of biopolymers. Maurice Gueron, Ecole Polytechnique (Palaiseau), utilizes a very simple and classical NMR measurement of proton exchange lifetimes in nucleic acids. In these systems, proton exchange occurs by opening of the base pairs. One can then look at the base pair lifetime (in the range of 1-40 ms) for each resolved base pair. I was amazed that small changes in the overall physical structure of the nucleic acid would affect these exchange times by orders of magnitude and, furthermore, that such large changes in base pair opening rates seem to track with biological activity. The base pair lifetimes do not appear to depend on their nearest neighbors. Even the nonspecialist catches some of the excitement as these results are integrated into the understanding of molecular recognition.

Solid-State Physics. Studies of incommensurate systems seem to be pursued most vigorously in Europe. Robert Blinc, University of Ljubljana, Yugoslavia, showed two systems--barium sodium niobate and biphenyl--in which the incommensurate order parameter has four components, rather than the customary two. Below about 40K, these systems can freeze into two possible ordered states. For deuterated biphenyl, the deuterium lineshape is quite diagnostic and indicates a *stripe-like* ordering, rather than a *quilt-like* ordering.

In vivo NMR and Imaging. In MRI, George K. Radda, Oxford University, U.K., has extended *in vivo* phosphorus spectroscopy to provide some spatial discrimination. Phosphorus spectra have been used earlier in MRI to indicate metabolic states. Radda showed substantial changes in the phosphorus spectrum (and therefore in the cell energetics) as one looks further into the human brain. Preliminary and very exciting results on the heart showed similar results. In this noninvasive way, one sees the changes in chemistry after exercise. The MRI is not only useful in clinical applications but will contribute to our understanding of human biology.

Paul T. Callaghan, Massey University, New Zealand, has pushed NMR microscopy quite far. For such microscopy, resolution is determined by the available signal-to-noise ratio from an individual volume element (voxel). Callaghan estimates a minimum voxel size of $(7\text{microns})^3$ for protons at a resonance frequency of 400 MHz. As linear dimensions of this minimally detectable voxel scale weakly with resonance frequency, Callaghan was able to show impressive results even on a 60-MHz system.

Conclusion

The 1989 ISMAR prize was awarded to John S. Waugh of the Massachusetts Institute of Technology, Cambridge. As Waugh has been quoted in the late 1960s as declaiming that NMR was dead, it fell to him to explain why such an obituary was premature. Waugh pointed out that magnetic resonance (primarily NMR, but lately electron spin resonance) is the only spectroscopy in which the Hamiltonian determining the time evolution of the system can be changed so radically and with such ease by *the* experimenter. Said another way, there is no such things as the NMR experiment. One has all sorts of tricks to play, to suppress certain interactions so that others can be studied more cleanly. Such an explanation is at the heart of why magnetic resonance is so vital 45 years after

its inception and 20 years after its announced death, and why meetings as diverse as ISMAR perform the important function of bringing together its rather disparate practitioners to share ideas.

Symposium on 21st Century Aviation

by Dr. Robert E. Machol, Federal Aviation Administration

Background and Introduction

On September 5-8, 1989, the Federal Aviation Administration (FAA) and the U.S.S.R.'s Ministry of Civil Aviation cosponsored a conference entitled "Aviation in the 21st Century: Problems and Solutions." The conference was held at the SOVINTSENTR, a new, modern facility in the heart of Moscow, colocated with the Mezhdunarodnya Hotel. This conference was a followup to the FAA-sponsored "Symposium on Aviation Systems Concepts for the 21st Century," held in 1988 at the Transportation Systems Center, Cambridge, Massachusetts. There were 400 attendees; more than half were from the U.S.S.R. countries, but U.S. and Western European attendees participated.

The Russians were extraordinarily hospitable hosts; the simultaneous translation worked impeccably, as did all of the other mechanical meeting arrangements. Most of the speakers were Russians or Americans, but there were also presentations on new technology aircraft and cockpit technology from Airbus; a paper on new Japanese airports, including those built on water, by Misao Matsumoto; a paper on future air traffic control operational requirements by Oskar Warns, Eurocontrol; and a paper on International Cooperation/Implementation of Future Aviation Systems by Brian O'Keeffe, Australia. For a complete report on the symposium, contact Joseph Del Balzo, AXD-1, FAA, Washington, DC 20591.

Joseph Del Balzo, Executive Director, FAA, Professor Anodina, and Aleksandr Aksenov, Deputy Minister of Civil Aviation, U.S.S.R., cochaired the meeting. Assad Kotaite, President of the Council of the International Civil Aviation Organization, opened the meeting and indicated the strong support throughout the international aviation community for this meeting. On the fourth afternoon, most of the delegates journeyed to Moscow's Sheremetyevo Airport. The U.S.S.R. exhibited its newest aircraft, including one airplane that flies on methane or hydrogen, and several new jets with all-glass cockpits.

Presentations

The technical sessions, all plenary, consisted of new aircraft, airports, human factors, and air traffic control. On the final morning, research tools were discussed.

Grigoriy Biushgens, Deputy Director of Central Hydrodynamics Institute, TSAGI, presented a paper in which he stated that the 21st century will see improved aerodynamics and construction materials (including composites), and more powerful and fuel-efficient engines. Safety will be improved because of extensive flight control automation, while protecting the ecology by limiting noise, sonic boom, and air pollution.

Anatoly Polskiy, Director of Research and Development for Aviation Industry, said that the cockpit of 21st-century aircraft would have

- Integrated system of indicators, signals, and controls
- Automated stability and controllability function of aircraft
- Nonplatform inertial navigation system
- Automated functions of airplane operation
- Improved characteristics of classical means of landing and a new microwave landing system
- Expanded critical flight regime warning function, including collision avoidance
- Increased accuracy in localizing equipment malfunctions.

William Small, Bechtel, pointed out that the Dallas/Ft. Worth Airport expects to handle 100 million passengers by 2010. This translates into 60,000 passengers, visitors, and employees in the terminal area during a peak hour. The airport will need 250 aircraft parking positions and 80,000 automobile parking spaces. Additionally, the terminal must provide the commercial variety of a city center. He spoke of the uses of computer-aided design for such tasks as checking wing-tip clearances and loading bridge swing and extension. At operating terminals, computers are already handling aircraft gate assignment, crew and aircraft scheduling, yield management, and airside access control. Automatic linking of tickets, boarding passes, and baggage tags, as well as computerized passports, will further expedite passenger processing. Increased use of artificial intelligence should benefit airline and airport decision making.

A. Stolyarov, Chief Pilot of Aeroflot, reiterated that pilot error causes most aircraft accidents, but indicated that many mistakes were inaccurately ascribed to the crew. These mistakes must be isolated and blame determined; then, reasons must be discovered and eliminated. He emphasized selecting, preparing, and training crews; social and daily conditions for pilots and organizing their flight work, as well as the classical cockpit ergonomics. Training methods must be created that inculcate correct habits for controlling and managing the aircraft. The training must be independent of the administration. We need electronic information display systems that make it possible to minimize and operationally change the information. He spoke about biocybernetic control systems that relieve eyestrain, provide control by voice and body position, and create physiological sensations when controlled actions are performed.

Robert Simpson, MIT, spoke of separation assurance. The large separations now required to avoid intersecting aircraft trajectories must be reduced if we are to increase

the capacity of the ATC system. As this is being done, more control of aircraft trajectories will go from the pilots to the controllers, with the pilot retaining a veto. Simpson distinguished between conflict-management and hazard-management processes. Conflict management is strategic and uses only information on planned trajectories. Conflict criteria depend on aircraft navigation and guidance and the frequency of pilot blunders. Hazard management involves tactical real-time intervention by either pilot or controller to avoid unsafe, unplanned encounters between aircraft. Hazard criteria depend on the quality of airborne and ground surveillance and communications systems and the frequency of pilot or controller blunders.

Analogous to today's flight control systems (FCS) in today's cockpits, there will be a ground control system (GCS). The GCS will detect conflicts and present suggestions to the ground controllers for resolution of hazard. The controller would issue this resolution through the GCS via the air/ground digital data link to be displayed in the cockpit. In the cockpit, there would be two buttons: (1) an *Accept and Acknowledge* button to confirm the hazard resolution command via the GCS; and (2) an *Execute* button to transfer the digital hazard resolution command into the FCS. In a still later stage of development, there will be only one button in the cockpit--a *Veto* button to stop the FCS from responding if the pilot thinks the controller command is unsafe.

Vladimir Ivanov, GLAVKOSMOS, and Jerry Bradley, FAA, gave a joint paper on GPS/GLONASS. The U.S. military is developing the GPS system to put 21 satellites in space, which will permit very precise navigation (approximately 100 meters). The Soviets are developing the GLONASS system, a direct counterpart. In the remarkable atmosphere created by glasnost, the U.S. and the U.S.S.R. have exchanged data on the frequencies, codes, and other details of these systems, and a single receiver is being designed that can use satellites simultaneously from both systems to obtain more precise position.

Fourth International Workshop on Desorption Induced by Electronic Transitions

by Professors Hideo Sambe and D.E. Ramaker, Department of Chemistry, George Washington University, Washington, D.C.

Introduction

The International Conference on Desorption Induced by Electronic Transitions (DIET IV) (the fourth in a series of DIET meetings, beginning in 1983) was held in Gloggnitz, Austria, on October 2-4, 1989, and organized by the Institut für Allgemeine Physik Technishe Universitat, Wien. The DIET IV was held at a small resort hotel (Burghotel, Kranichberg) located about 50 miles south of Vienna and attended by 81 international scientists. Partial support for this meeting was provided by the Bundesministerium für Wissenschaft und Forschung.

The scientific program consisted of 33 oral presentations and one poster session; the conference language was English. Many of the oral presentations produced vigorous debates in an informal atmosphere. Each oral presentation was limited to 20 minutes followed by up to 10 minutes of discussion. The diversity of the participants contributed to a lively interchange of ideas and points of view. A book of one-page summaries was very useful for following the presentations. A large amount of material (33 oral presentations and 31 posters) was presented.

The conference proceedings will be published by Springer-Verlag, Heidelberg, Federal Republic of Germany (FRG), as a special volume entitled "DIET IV" in *Springer Series in Surface Science* (R. Gomer, editor). The published proceedings for the previous DIET conferences have become highly referenced and authoritative sources on desorption phenomena. All contributed papers to this volume will be refereed, and the volume should be a valuable, high-level description of the state-of-the-art research in DIET studies.

Topics Covered

The conference covered a wide range of topics spanning several diverse disciplines:

- Desorption resulting from electronic transitions induced by electrons stimulated desorption (ESD), photons stimulated desorption (PSD), or ion-stimulated desorption (ISD) impact
- Desorption involving molecular adsorbates, erosion of alkali halides and condensed gases, and surface chemical reactions induced by electron or photon impact
- Applications of DIET to semiconductor processing, plasma material processing, and biological systems.

As in the preceding DIET conferences, the main focus of this conference was on the identification and elucidation of the underlying electronic mechanisms associated with the desorption of atoms or molecules from surfaces. On a fundamental level, the DIET studies were concerned with the basic questions of surface physics and chemistry, such as the geometrical and electronic structure of atoms and molecules on surfaces. In addition, the dynamics of bond-making and breaking of surfaces were studied.

Evolution from the Previous DIET Conferences

In DIET processes, the desorbing species can possess either a neutral, positive, or negative charge. At the first two conferences in the series (1983 and 1985), the experiment data presented involved mostly desorption of positive ions. Little data on neutral and negative ion desorption were reported at these early meetings. At the third conference in 1987, the number of papers reporting neutral desorption increased considerably. In this fourth

conference, papers reporting desorption of neutral particles in the ground and excited states outnumbered those for positive ions.

Papers reporting negative ion desorption experiments were, however, still relatively rare. M. Bernheim and T.D. Wu, Universite Pari-Sud, France, presented their cathode electrostatic lens setup to decelerate an electron beam at the vicinity of the investigated surface and also obtain a high collection efficiency for the negative ions. Also, T.E. Madey, Rutgers University, New Brunswick, New Jersey, with S.A. Joyce and A.L. Johnson, National Institute of Standards and Technology, Gaithersburg, Maryland, reported ESD ion angular distributions of negative ions. At the next DIET meeting, which is scheduled for spring 1992 in Santa Fe, New Mexico, we expect many more presentations on negative ion desorption.

A study of neutral, positive, and negative species desorption from the same sample could provide a detailed and more complete picture of the various desorption processes, which at this time are still not clearly understood.

Another trend observed at this conference was an increasing number of presentations on PSD by synchrotron radiation. Synchrotron radiation, providing an intense polarized photon flux with well-defined energy, can prepare well-defined initial excitations, both in terms of energy and symmetry. For many DIET experiments, in general, we do not have control over the initial excitations. Information on the initial excitations helps to play an important role in understanding the underlying physics of desorption.

Compared to the previous conferences, the present interest in PSD with synchrotron radiation appeared to be shifted from core excitation to valence excitations, which take place around 30-40 eV. In our view, valence excitation around 10 eV, where the lowest photodissociation processes take place, together with detection of neutral atoms in the ground and excited states, could provide some detailed information on the desorption processes.

An entire afternoon session was devoted to desorption from alkali halides. A very interesting history is evident in this area. At the DIET I and II meetings, it was generally believed that the excited alkali atoms that desorb from the surface came from intrinsic, direct DIET processes. At the DIET III meeting, it was indicated that most, if not all, of the metastables were produced from excitation in the "plasma" of neutral alkali species formed above the surface; i.e., a secondary process. Evidence for this came primarily from the quadratic dependence of the yield on the electron beam current. However, at this conference, G. Betz and his group at the Technische Universitat Wien gave strong evidence for a surface intrinsic process as well as the secondary process for the generation of excited alkali atoms. Indeed, they also provided data showing that at different temperatures and beam currents, each process could be made to dominate.

Since desorption often results from photodissociation or dissociative electron attachment of adsorbed molecules, a general knowledge about such processes in the gas phase can be very valuable for understanding them for physisorbed adsorbates. Because of this connection, in the preceding three conferences, experts in gas phase phenomena were invited and gave stimulating lectures. However, at this fourth conference, we had only one gas-phase paper, and that was in the poster session. In our view, we missed an excellent opportunity to hear from such experts, since Europe, especially England and France, has excellent and well-known scientists in these fields.

Three Important New Areas

1. A surprisingly large number of papers (9 out of 64) addressed desorption from rare gas solids or from molecules physisorbed on a rare gas surface. Rare gas solids are one of the simplest of solids, and physisorbed molecules on a rare gas surface might be expected to qualitatively simulate molecules suspended in space. Desorption processes for these systems are thus expected to be easiest to comprehend. This may be the reason for the attraction of many workers to these particular systems. Indeed, a considerable progress in understanding these systems has been made. For example, I. Arakawa, Gakushuin University, Japan, with M. Sakurai, Institute of Plasma Physics, Japan, identified successfully two distinct PSD processes for Ar* from solid Ar. This identification became possible because the initial excitation was controlled, the desorption process was monitored by measuring the kinetic energy of the desorbing Ar*, and the approximate potential curves for the Ar-Ar* interaction were known.

The PSD from another van der Waals solid, namely condensed CH_3I, was reported by D. Feldmann, J. Kutzner, and K.H. Welze, Universitat Bielefeld, FRG. Several interesting differences from gas phase behavior were observed indicating that DIET studies with van der Waals solids can be very profitable in understanding the underlying physics of desorption.

2. A new mechanism for laser-induced desorption (LID), photodissociation, or photochemistry involving molecular adsorbates on metals, termed the *hot electron mechanism*, was employed by several researchers to explain their experimental results. The *hot electron mechanism* implies that incoming photons excite substrate electrons, namely, hot electrons, which excite adsorbates on the surface resulting in desorption of adsorbate fragments, or at least some photochemical reaction at the surface. This *hot-electron* mechanism was discussed with enthusiasm, but no consensus was

reached as to its validity. This is an obvious area for future strong activity.

A very interesting paper was presented by T.A. Green, Sandia National Laboratories, Albuquerque, New Mexico, and coworkers, and N.H. Tolk, Vanderbilt University, Nashville, Tennessee, and coworkers, who proposed a hot hole diffusion theory for ESD of ground-state, neutral metal atoms from alkali halides. Although this was first proposed at this conference, this proposal appeared to be no more controversial than the *hot electron mechanism* for the LID and other processes mentioned above.

3. Perhaps one of the most novel and interesting practical papers was given by F. Trager, Universitat Heidelberg, FRG, who illuminated with visible laser light small Na metal clusters deposited on a substrate. His results suggest that a collective electron oscillation precedes the desorption of metal fragments. The important result was that very uniform and narrow size distributions of the metal clusters could be obtained, and that the size distributions could be selected simply by varying the wavelength of the laser light.

Summary

In our view, good progress has been made in our understanding of DIET processes in the last 2 years; however, many fundamental questions remain unanswered. An international, coordinated effort, stimulated by this conference, is necessary to answer these diverse and formidable questions.

Conference on Critical Currents in High-Temperature Superconductors

by Harold Weinstock, Program Manager for Superconductivity, Air Force Office of Scientific Research, Bolling Air Force Base, Washington, D.C.

The second conference on Critical Currents in High-Temperature Superconductors was held October 24-25, 1989, at the Nuclear Research Center Karlsruhe (KfK), Federal Republic of Germany and was attended by 150 individuals from 20 countries and 4 continents. In attempting to do anything practical with a superconductor, critical current (or critical current density, j_c) is perhaps the most important physical parameter once one has achieved a temperature less than the superconducting transition temperature (T_c). Raising the value of j_c in the new class of ceramic high-temperature superconductors (HTS) has become a major challenge. This is the key to the degree that these materials will impact a wide range of electromagnetic technologies.

Early in the era of HTS above liquid nitrogen temperature (77K), which began in 1987, thin films of $YBa_2Cu_3O_{7-x}$ (or the "123" phase of YBCO) were fabricated with j_c in excess of 10^6 A/cm^2 at 77K, a value quite adequate for many applications (assuming other criteria can be met). However, there appear to be many practical barriers to achieving such high values of j_c in thick films and bulk specimens for fabrication into wire or ribbon suitable as power cables and magnet windings (to name two major applications).

In a nutshell, the problem in increasing j_c in bulk HTS arises because of conflicting requirements. The relatively low j_c values arise primarily because of two factors: (1) intergrain boundaries provide weak linkage for the supercurrent, and (2) the pinning energy and the number of pinning sites for vortices (of normal current) are governed by lattice defects such as intergranular interfaces. To obtain a high j_c, one wants a minimum of intergranular regions through which current must flow, and at the same time one would like a high density of strong pinning sites to keep the (normal-region) vortices from breaking loose and producing a voltage which destroys the superconducting state. Thus, on the one hand, it is desirable to minimize intergranularity and other lattice defects; while on the other hand, one wishes to maximize the number of effective pinning centers. This problem was overcome in the older, now so-called low-temperature, metallic superconductors (LTS), but there is more of a challenge in the HTS materials because of a much smaller inherent electron-pairing coherence length, on the order of 1 nm, and pinning energies that so far appear to be somewhat lower.

One can summarize the conference by saying that substantial progress has been made in increasing j_c in bulk material and in usable wires, particularly in the presence of sizable magnetic fields. However, there was no unanimity as to how to solve the above-stated problems or even what the nature is of the vortices in HTS materials. Thus, several applications now appear within reach in the near future. Furthermore, there is optimism that additional progress and subsequent applications are possible. Some of the work that gave rise to this optimism is summarized below.

Perhaps the greatest interest centered on the high j_c values found for bulk YBCO materials made by Masato Murakami of Nippon Steel Corporation (but now leading a group at the Superconductivity Research Laboratory of ISTEC in Tokyo) and for those made by K. Salama's group at the University of Houston, Texas.

Murakami's sample preparation is referred to as the quench-and-melt growth (QMG) process. This entails rapid heating to 1,400 C, a quench to room temperature, and subsequent reheating to produce a precipitate of 211 phase (Y_2BaCuO_5) needles embedded in a liquid phase, and finally slow cooling. This QMG process appears to suppress crack formation, promote oxygen diffusion, and enhance flux pinning. Critical current measurements using current transport, magnetization, and ac techniques were made. It was found that at 77 K and a magnetic field of 1 T, the j_c was in excess of 35,000 A/cm^2, a record for a bulk sample, although not all specimens made were that

good. This lower limit value for j_c is greater than that found for single crystals of YBCO. One can explain this by noting that flux-creep studies yielded a pinning energy (in zero field and 77 K) of only about 0.1 eV for single crystals and between 1 and 2 eV for QMG specimens. Murakami feels that if one can control the fine dispersion of 211 precipitates, then higher j_c values can be reached. He further indicated that a process may have been found at ISTEC to control the distribution of these precipitates.

Salama's sample preparation was not presented in detail at the conference, as this information had appeared earlier in the literature (Appl. Phys. Lett. 54, 2352, 1989). However, a group at KfK and one at the Naval Research Laboratory (NRL) reported on j_c measurements made on Salama's specimens. Briefly, in Salama's earlier publication, a liquid phase processing method on YBCO was used. The result showed that slow cooling through the peritectic transformation produces a microstructure with long plate type, thick grains over a wide area. Making continuous direct current measurements (at 77 K and zero magnetic field), a current density up to 18,500 A/cm^2 was obtained before contact problems occurred. Pulsed current measurements yielded over 62,000 A/cm^2 for a 10-ms pulse and over 75,000 A/cm^2 for a 1-ms pulse before contact burnout. With this last pulse length, a current density in excess of 6,000 A/cm^2 was found in a 0.6-T field.

At the conference itself, Tom Francavilla, NRL, reported on transport j_c measurements on four of Salama's samples at 77K and in fields up to 12 T oriented parallel to the c-axis of the aligned grains. The results were found to be sample dependent, with j_c values ranging from 700 to over 2,200 A/cm^2 in fields between 5 and 9 T. One sample was measured in a 12-T field oriented perpendicular to the c-axis and was found to have a critical current of 760 A/cm^2. The same four samples were measured by the KfK group headed by H. Kupfer which used both transport and magnetization measurements to determine j_c. Perhaps the most significant result obtained was agreement with the NRL data in a 5-T field. They did find a strong magnetic field dependence for fields below 1 T. With pulse measurements in zero or very low field, they found slightly lower values than those reported by Salama earlier but still in the range of 10,000 to 50,000 A/cm^2. This difference can be the result of different measurement criteria or some degree of aging. The KfK group further reported on studies of these samples in an attempt to resolve the two major problems limiting j_c: the weak coupling of the superconducting wave function at planar defects, and the thermal relaxation of the pinned flux lattice. They investigated the magnetic flux profile, ac susceptibility, and dc magnetization. In zero field and 77K, they found the ratio of the pinning to the thermal energy (U_o/kT) to be about 50. Such a value should be increased by another factor of 5 to rival practical LTS materials in power and magnet applications. Furthermore, the j_c at 77K of 50,000 A/cm^2 at zero field and of 15,000 A/cm^2 at 1.2 T are about one order of magnitude away from the practical values required.

Doug Finnemore, Ames Laboratory, Iowa State University, summarized many of the factors that control critical current: cracks, microcracks, grain boundaries (caused by second phases, impurities, dislocations, and vacancies), oxygen vacancies (resulting in a suppressed order parameter), and the addition of iron. He described work that had been accomplished by his group to determine the defects that produce pinning and to obtain the energy per unit length of a vortex. This work was carried out on the thallium-based (2223) HTS materials, the neodymium cerium class of copper oxide electron superconductors, and YBCO doped with iron. In no case did he see evidence for a melting of the flux line lattice. Finnemore also described a promising new process called gas jet fiberization--actually an old process in regard to other ceramics--in which long, slender fibers of bismuth-based HTS, between 0.3 and 3 μm in diameter and on the order of a centimeter long, are embedded in a silver matrix. This process evolved from a discussion with and involved the collaboration of Babcock and Wilcox scientists. The resultant fibers exhibit a full Meissner effect and are under further study.

Among other interesting contributions, it is worth noting the silver-stabilized HTS wires produced by J. Tenbrink et al., Vacuumschmelze. Using a *powder-in-tube* technique for both YBCO and BSCCO ($Bi_2Sr_2Ca_1Cu_2O_{8+x}$ or "2212") encased in a silver sheath, the j_c in the former was found to be limited by weak links, but there were virtually no weak links found in the BSCCO/Ag wires. Above approximately 20K, j_c in this latter material seemed limited by flux creep, while at lower temperatures the creep was not evident. At 4.2 K, j_c up to 57,000 A/cm^2 was observed, while it dropped to only 15,000 A/cm^2 in a 26-T field. This leads to the intriguing possibility of producing high-field superconducting magnets of HTS material at liquid helium temperature in which the limiting factor would be the strength of the structural support. Many other papers described fabrication processes involving either the addition of silver to an HTS powder or the embedding of HTS powder in a silver matrix. For example, J. Lohle et al., ETH-Zurich, were able to embed between 19 and 361 filaments in silver wires as thin as 100 um in diameter and in lengths exceeding 100 meters. Papers presented by Mineo Ito et al., Kinki University, Japan, and by Wuning Chen et al., Nanjing University, Peoples Republic of China, both showed modest enhancements in j_c as a result of adding a few percent of silver, although it is possible that these enhancements are strain related.

From the interaction of a panel of experts at the close of the conference, it was clear that there are many unanswered fundamental questions. Perhaps this can best be summarized by quoting a random comment from an unidentified attendee: "I've heard six different models of flux creep, almost all the same, but no one really knows what is going on!" However, despite this uncertainty, the conference revealed many impressive accomplishments over the past year or so, and the future appears bright for HTS films and wires, and for the applications to which they will be applied.

ONREUR REPORTS AND MAS BULLETINS

Reports

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Computer Science

ESPRIT II, by J.F. Blackburn. **(90-1-R)** The second 5-year phase of the European Strategic Program for Research and Development in Information Technology (ESPRIT II) began at the start of 1989. (For information on the first phase, see *ESNIB* 89-03:13-16.) This report will provide more detail on ESPRIT II, which is funded at 3.2 billion European Currency Units; half will come from participating companies.

This report includes a list of all approved projects in: Information Processing, Office and Business Systems, Computer Integrated Manufacturing, Information Exchange System, and Basic Research. A brief description of each of the 47 projects currently supported within the Information Processing Systems area is included.

Cable Television and Satellite Broadcasting, by J.F. Blackburn. **(90-2-C)** Sponsored by the Financial Times, this 2-day conference was the eighth in the annual series. This particular conference marks the end of the first year of the Sky Television network's operation in the U.K. The conference was held just before British Satellite Broadcasting (BSB) goes into operation.

With speakers from the U.K., the U.S., France, Japan, and the Netherlands, attendance exceeded all previous conferences. The 400 participants came mainly from the U.K., but also represented were France, the Netherlands, U.S., Australia, Spain, Norway, Canada, Switzerland, Denmark, Federal Republic of Germany, Finland, Monaco, Belgium, South Africa, Italy, Luxembourg, Irish Republic, and Malta.

MAS Bulletins

The following Military Applications Summary (MAS) Bulletins were published between 26 February and 24 May 1990. The MAS Bulletin is an account of accomplishments in European naval research, development, and evaluation. Request copies by number from ONREUR.

1-90 Pyrocool: The Generation of High Purity Gas from Solids

2-90 Royal Ordnance Develops New Signal Flare Kit

3-90 Explosive Cutting Tape - ROECT

4-90 Submarine Communications Multi-Function Antenna

5-90 Submarine Communications and Navstar Antenna

6-90 Submarine Communications Low Profile Antenna

7-90 Expendable Communications Buoy

8-90 Submarine Integrated Communications Mast

9-90 14th International Pyrotechnics Seminar Proceedings

10-90 SIMRAD Subsea Split Beam Transducer for Phase-Angle Measurements in Narrow Beam Sonars

11-90 Modular Sea-Skimming Towed Target System

12-90 The LR6000 - A British-Designed Long-Range Autonomous Submersible

13-90 Ocean Surface Current Radar Update

14-90 Ocean Surface Current Radar II

15-90 De-Bug Fuel Decontamination Unit

16-90 Seastreak - High Velocity Close In Weapon System

REPORTS ON EUROPEAN SCIENCE AND TECHNOLOGY FROM OTHER COMMANDS

Reports

Information on each of the reports listed below was furnished by the following activity. Requests for copies of or information about the document should be addressed to:

EOARD - European Office of Aerospace Research and Development, Box 14, FPO New York 09510-0200

Delft Institute of Microelectronics and Submicron Physics, by Dr. Eirug Davies, EOARD. (5 pp) [EOARD-LR-90-005]

Delft University of Technology, the Netherlands, is forming a university-associated microelectrics center. Delft University has traditionally concentrated on bipolar and silicon sensor technology and this will be expanded to include a CMOS capability. A recently published monograph entitled "Silicon Sensors" provides an overview of the sensor activities. This book may become a standard text on mechanical based as well as other forms of silicon sensors.

Electromagnetic Launch Research at Prins Maurits Laboratory Pulse Physics Laboratory, Delft, by Dr. Vince Donlan, EOARD. (10 pp) [EOARD-LR-90-019]

In 1987, the Prins Maurits Laboratory (PML), Netherlands Division of National Defense Research, established a Pulse Physics Research Group to conduct a cooperative research program with the Strategic Defense Initiative Organization on electromagnetic launch (EML) technology. A rail gun facility powered by a 6.7-MJ homopolar generator and inductor power supply, including a 20-m instrumented range, has been put into operation. Additional rail gun facilities are being built consisting of a 250-KJ capacitor bank and a bipolar battery Kapitza power supply. This report describes these facilities, along with current and future EML research.

European Conference on Advanced Materials and Processes, by LTC James G.R. Hansen, EOARD. (8 pp) [EOARD-LR-90-006]

Recently, the Federation of European Materials Societies presented the first in a series of biannual major European materials conferences--EUROMAT '89--in Aachen, Federal Republic of Germany (FRG). Four research projects presented at the conference are summarized in this report: (1) Production of Intermetallic Phases by Solid State Reaction of Cold Extruded Elemental Powders, GKSS, FRG; (2) Development of a New Nickel Based Single Crystal Turbine Blade Alloy for Very High-Temperature, ONERA, France; (3) The Preparation of Ti-based Metal Matrix Composites Via a Casting Route, University Birmingham, UK; and (4) Metal Ceramic Composites for High-Temperature Applications, University of Aachen, FRG.

General Electric Company Marcoussis Laboratories, France, by Dr. Vince Donlan, EOARD. (5 pp) [EOARD-LR-90-009]

The Marcoussis Laboratories are the location of central research for the giant General Electric Company (CGE) of France. Their main research and development (R&D) areas of fiber optic communications, energy, robotics, and information processing support the product development efforts of the various companies comprising the CGE Group. Fiber optics R&D supports undersea telecommunications; energy and robotics research supports the nuclear power, battery, and transportation sectors; and information R&D (consisting of expert systems, AI, and software engineering) supports all sectors of CGE.

Thomson-CSF Electronics and Defense Systems, by Dr. Vince Donlan, EOARD. (7 pp) [EOARD-LR-90-010]

The electronics and defense sector of Thomson-CSF accounts for the bulk of the company's income. Current activities described in this report are: (1) Aerospace Group - airborne radars, displays, and ECM equipment, missile seekers, and laser designators; (2) Weapons and Weapon Systems Group - AA and ASW equipment; (3) C^3I Group - air traffic control systems and communications equipment; and (4) Electronic Components Group - electron tubes, ICs, UV/Vis/IR CCDs, MMICs, ASICs, and microwave hybrids.

Belgium Interuniversity Microelectronics Center, by Dr. Eirug Davies, EOARD. (4 pp) [EOARD-LR-90-012]

The Belgium Interuniversity Microelectronics Center--IMEC--is deservedly regarded as Europe's foremost microelectronic center. The IMEC has a superbly equipped facility that was purpose-built in 1986. Currently, staff is around 350. A five-inch line utilizing optical or electron beam lithography processes both CMOS and BiMOS. Research on thin-film silicon technologies concentrates on zone melt recrystallization, and novel circuitry based in Simox wafers are also under evaluation. About one sixth of the laboratory's effort is in GaAs.

Gallium Arsenide Power Devices at Telletra, by Dr. Eirug Davies, EOARD. (4 pp) [EOARD-LR-90-014]

Telletra, located in Vimercate, Italy, is a leading manufacturer of telecommunications equipment that produces GaAs-based power amplifiers for its own internal needs. Transistors in the 8-12GHz range were first produced in 1985, and the technology has gradually evolved to produce the present 4-8 watt devices. Chloride vapor phase epitaxy and later ion implantation have both been used in their manufacture. A Telletra-patented air bridge was recently introduced that interconnects gates rather than sources.

Electro-Optic and Photorefractive Materials Research, by Dr. Stacey Lazdinis, EOARD. (12 pp) [EOARD-LR-90-017]

This report describes Prof. Peter Gunter's work in nonlinear optics, electro-optics, and the photo-refractive behavior of nonlinear crystalline materials. Prof. Gunter is with the Institute of Quantum Electronics at the Swiss Federal Institute of Technology in Zurich. Special emphasis is given to his detailed studies of anisotropic diffraction by photorefractive gratings using Potassium Niobate ($KNbO_3$).

Messerschmitt-Boelkow Blohm Designs Eurofighter, by LTC James G.R. Hansen, EOARD. (8 pp) [EOARD-LR-90-021]

In a dramatic break with conventional practice, Messerschmitt-Boelkow Blohm (MMB) GMBH has designed the Eurofighter with an ultimate factor of safety of 1.4 (versus standard 1.5), by using the aircraft flight control system to ensure that maneuver limit loads are not exceeded. The design saves about 600 Kg. The Eurofighter makes significant use of CFC co-cured and co-bonded structure. In another development, MBB LaGrange computer software solves multi-criterion optimization problems, such as designing a minimum weight composite fin with maximum aeroelastic efficiency for a supersonic aircraft; i.e. the Eurofighter. Smart structure is also an expanding area of research at MBB.

SURMET, FRG - Metallurgy and Explosive and Compaction, by LTC Chet Dymek, EOARD. (10 pp) [EOARD-LR-90-026]

SURMET is a small company in Aachen, FRG, that is establishing its niche in the materials sciences world. SURMET is combining the techniques of powder metallurgy and mechanical alloying with the explosive compaction method of forming. SURMET can create and study new alloys, including their composites with ceramics. They then investigate these materials which can have exceptional properties because they are consolidated at low temperature by the shockwave of explosive compaction. Low temperature is important in that it allows retention of the properties of the mechanically alloyed materials, including nanostructural aspects. Their growing expertise in using this method to join dissimilar metals extends to welding together tubes or rods, forming laminates, and applying coatings.

THE EMBASSIES: TECHNOLOGY ROUNDUP

Federal Republic of Germany

For further information on FRG items, contact Mr. Edward M. Malloy, Science Counselor, American Embassy, Bonn, APO New York 09080-7400.

FRG Government and Utility Operators Debate About Storage of Unreprocessed Nuclear Wastes

Recently, The Conservative Daily, Frankfurter Allgemeine Zeitung (FAZ) carried a lengthy article concerning the disposition of spent nuclear fuel. The article describes the debate in the Federal Republic of Germany (FRG) among electrical utility operators and government officials. The debate is over the alternatives of either reprocessing the FRG's nuclear fuel in France and the U.K. or using the once-through option of direct storage of spent fuel in a permanent repository. This debate results from the decision last year by utility operators and the FRG to abandon the Wackersdorf Reprocessing Plant Project. Commercial and intergovernmental negotiations for reprocessing spent fuel in Cogema, France, and BNFL, U.K., are nearly complete. Nevertheless, many utility operators increasingly favor direct storage. This option, however, depends on the availability of the Gorleben Repository for direct storage of spent fuel. That caveat aside, politically and commercially, the balance of forces favor the direct storage option of most of the FRG's spent nuclear fuel.

According to Federal government nuclear officials, the commercial negotiations with Cogema and BNFL for reprocessing services are not yet complete, but the intergovernmental agreements are also ready to be signed. Also, they agree that direct storage is a viable option and that the Gorleben facility is large enough to accommodate the spent fuel from the FRG's nuclear park. One official recognized that the atomic law must be amended because it now stipulates reprocessing as the means of managing spent fuel disposition. Otherwise, existing operating licenses could be challenged if operators choose the direct storage option. Another expert claims that the FRG could recycle in mixed oxide fuel elements all the plutonium recovered from reprocessing of spent fuel from the FRG's reactors.

The debate, which dates only to last year when the utility operators and the FRG decided to abandon the Wackersdorf Reprocessing Plant Project, is likely to drag on. The FAZ article indicates, however, that the direct storage option is gaining ground among utility operators. The option is cheaper and less complicated--provided supplies of enriched uranium fuel remain relatively inexpensive and provided the Gorleben repository becomes available for permanent direct storage of spent fuel.

Integrated Circuit Development in the FRG

As part of the long-term industrial technology policy, the Federal government has funded research and development (R&D) in integrated circuits and related technologies since the 1970s. Funding peaked in 1987 at over $150 million and dipped to almost $130 million in 1990. Currently, the program focuses on developing advanced megabit chips and x-ray lithography, Gallium Arsenide technology, and computer-aided design of integrated circuits. The centerpiece of the Federal program, until its recent successful conclusion, was the support totaling $200 million for the development of the 1-megabit static and the 4-megabit dynamic RAM chip in the mega-project, a joint effort by Philips and Siemens. Now the focus of Federal support for developing advanced megabit chips has shifted to the Joint European Submicron Silicon Initiative (JESSI) within EUREKA. The end of this $4-billion European project is to develop a 64-megabit chip. Under this program, the Federal government will provide industrial firms and scientific institutes about half the costs of approved projects. In pouring over a $100 million a year into R&D in advanced integrated circuits, the FRG wants to ensure a place for national firms in an industry perceived as essential for the FRG's economic security. The shift of focus from a national to a binational, and now to a European framework reflects the need of firms to cooperate and share the increasing cost burden of precompetitive R&D.

FRG Information Technology Research and Development

Part of a long-term policy of support for civil industrial technologies, the FRG has allocated more than $2.6 billion (DM 4.5 billion) over a 4-year period for information technology research and development. The strategy is comprehensive and will influence not only industry but higher education as well. Many feel that Federal funds, and increasingly, European funds, will be the key to FRG success in information technology. With a major obligation of this nature, the FRG is clearly sending the signal that it intends to do everything possible to not be left behind in this important field. Under its informatics program, the BMFT is fi-nancing research in microelectronics, information processing, communications technologies, as well as computer design and assembly technologies.

FRG Parliament Passes Genetic Engineering Bill

The FRG Federal Parliament passed a bill on genetic engineering over the opposition of the Social Democrats (SPD) and the Greens. The bill passed after several years

of interparliamentary and public discussion and investigations.

The law fills a legal vacuum, which has already led to discontinuing construction of a commercial production plant for human insulin. Scientists and research laboratories had drifted into other countries, especially to the U.S.

The law's purpose is to protect man's life, health, and environment against dangers of genetic engineering production processes and products. The law also regulates the application of genetic engineering, research on genetically modified organisms in closed laboratories, and in the environment.

In addition, the law covers commercial production, licensing procedures for production facilities, and liability regulations. The regulations authorizes the government to issue ordinances to provide a flexible reaction to the scientific and technological advancements and requirements. Further, the law establishes the Central Commission for Biological Society (Zentrale Kommission Fuer die Biologische Sicherheit - ZKBS), incorporated in the Federal Health Agency in Berlin. The ZKBS evaluates safety and supervises the installation of genetic engineering research laboratories, production plants, and manufacturing processes.

In January 1990, the Federal Upper House (Bundesrat) refused to accept the original bill--leading to additional hearings and finally to a complete revision. The final Parliamentary debate was sparked by controversy between the CDU/FDP coalition and the opposition parties, the SPD, and the Greens.

The Greens object to genetic engineering as a high-risk technology. The SPD accepts genetic engineering, but wants a more thorough revision and amendments, based on supplementary investigations and expert opinions on the risks of this technology.

Space - FRG's Busy Astronauts

Three Astronauts on Two 1992 Space Missions. At a recent press conference, the Chairman of the FRG Aerospace Research Establishment (DLR), Professor Walter Kroell, announced that for 1992, the DLR plans two missions using three German astronauts; the second FRG spacelab (D-2) mission with two Germans aboard the U.S. space shuttle and one German astronaut participating in a mission to the Soviet MIR Space Station. For both missions, the DLR will assume essential R&D activities for many experiments, as well as complete scientific management and crew training.

The 9-day, D-2 mission aboard the U.S. space shuttle is in its intensive simulation phase. There will be 90 sophisticated basic research experiments in material research, production process technology, biology, and medicine, as well as of earth observation and extraterrestrial research. Furthermore, 54 universities, 20 research institutes, and 16 industrial firms will contribute to the scientific program of the mission. The DLR contributes 13 experiments: 9 deal with material research; the other four cover earth observation and life sciences. The D-2 mission has a budget of DM 825 million, including DM 265 million launching fees for NASA and DM 290 million for payload facilities and scientific experiments to which industry only contributes DM 20 million ($11.5 million).

In contrast to the 90 D-2 mission experiments, the German contribution to the Soviet MIR Mission will consist of seven experiments. With the beginning of closer German-Soviet cooperation, the DLR also hopes to take advantage of the Soviet experience in long-duration space flights. In preparation for the MIR mission, the Soviets will supplement the German astronauts' basic training with 18 more months of training, including Russian language and Soviet Space Systems. They will also train on the centrifuge, in the low-pressure chamber, and at the Soviet simulation facilities.

Supplementary to the ready-to-be-signed contract on the FRG participation in a Soviet MIR Mission in 1992, the DLR has recently signed a cooperative agreement with the Soviet Institute of Biomedical Problems. This agreement points to a closer cooperation in space physiology, space medicine, space biology, radiation biology, and dosimetry. The agreement covers the exchange of scientists and joint experiments on ground and in space. In addition, the DLR is investigating opportunities for long-term cooperation with the Soviets, including participation in the Soviet MARS-94 Project.

After the D-2 mission, scheduled for spring 1992, a D-3 follow-up mission is planned for August 1994. In contrast to the preceding D-1 and D-2 missions, which will have been exclusively FRG scientific missions, the D-3 mission is planned for European participation.

Future European Astronauts Training Center in Cologne-Porz. According to a recent decision of the European Space Agency (ESA) Administrative Council in Paris, the future training center for European astronauts will be at the DLR's headquarters at Cologne-Porz. Together with the DLR's Crew Training Center (CTC), under construction, the European Astronauts Center (EAC) will form a unit for the complete theoretical, physical, and technical training of 30 to 40 European astronauts. The EAC construction costs are DM 250 ($143 million). The ESA will cover DM 200 ($114.5 million), while the Federal Ministry of Research and Technology and the State of North Rhine, Westphalia, appropriated the first DM 50 million ($28.5 million). In the final stage, the EAC will be equipped with mockups and simulation facilities of the European HERMES Space Shuttle and the Columbus Spacelab Modul, as well as a centrifuge and a water pool for the physical training of the astronauts. About half the ESA and DLR employees will jointly provide the 150-member staff.

Production Engineering and Computer-Integrated Manufacturing in FRG

The FRG spends about $2 billion a year supporting civil industrial R&D. Increasingly, this support is directed at enabling technologies (technologies that provide foundations for developing a variety of products); e.g., microelectronics, new materials, robotics, biotechnology, and production engineering. In the FRG, production engineering has virtually evolved into a separate scientific discipline. In universities, notably in Stuttgart, Berlin, Aachen, Dortmund, and Darmstadt, over 3,000 scientists and engineers conduct basic research in production engineering. The Federal government, through the German Research Society (DFG), provides over $25 million annually for basic research in production engineering. Probably more important is the applied research done at 15 Fraunhofer institutes with funds provided by both the Federal government and industry.

In 1983, the Federal government launched the first of two 5-year programs supporting production engineering. The goal is to incorporate into the traditional manufacturing processes the latest technologies: computer-aided design and manufacturing (CAD/CAM), computerized numeric control (CNC), computer-integrated manufacturing (CIM), as well as lasers, robots, and manipulators. Altogether, through 1992, the FRG will spend about $600 million for projects in over 1,200 firms, 90 percent of which have fewer than 500 employees. The funding agency is the Federal Ministry of Research and Technology (BMFT). The program's main parts are CIM development of new manufacturing and assembling technologies; and support measures, including basic research and technology assessment. The production engineering program covers developing and using new technologies in construction, mining, printing, electroplating, foundry, woodworking, industrial robots, machine tools, machinery components, and other industrial sectors. Some examples of projects are:

- PRIMOS: A $5 million project in which two research institutes and seven firms developed a modular computer-aided assembly planning system to assess individually or systematically assembly, product, and plant structural planning.
- FAMOS: Two European cooperative projects, one to develop an integrated assembly and logic system for small- and medium-size assembly units (water supply fittings, door locks, or mobile telephones); the other to develop a relay assembly pilot project to solve problems in the production of electromechanical components.

The major focus of the program is CIM. Not only is R&D supported, but a special effort disseminates recent developments in CIM technology through seminars, pilot projects, and consulting services. Standardizing CIM technology is another goal. Both European- and worldwide cooperative projects on standardization are funded in the European ESPRIT and BRITE programs. The Nuclear Research Center in Karlsruhe (KfK) coordinates the production engineering program as well as FRG participation in European programs of CIM standardization.

This 10-year Federal program, supporting production engineering, is directed neither at a glamour high-tech field like aerospace nor at ailing industries. Rather, it supports the modernization of traditional manufacturing. This includes some of the FRG's most dynamic and profitable industries. For example, one of the principal beneficiaries is the machine tool industry, which has had an annual increase in productivity of about 5 percent from 1985 to 1989. The four largest German machine tool manufacturers with sales of $200 million or more invest heavily in R&D: Deckel - 5.6 percent, Gildemeister - 4.9 percent, Trumpf - 6.0 percent, and Maho - 7.0 percent.

France

For further information on French items, contact Dr. Michael Michaud, Science Counselor, American Embassy, Paris, APO New York 09777.

French Biotechnology

Introduction. Defining, describing, and evaluating a country's ensemble of new technologies applied to living systems--known collectively as biotechnology--is inherently a formidable task. The French government has made the attempt at least twice. In 1982, a report was prepared establishing a mobilization program for the rise of biotechnology. Subsequently, in 1988 the Sautier report was prepared on biotechnologies. While even the latter is becoming dated, it still serves as the departure point for most official discussions about biotechnology. A third attempt at a national assessment of biotechnology--this time by the Parliamentary office for the Evaluation of Scientific and Technological Choices--should be completed in mid 1990.

When asked about the particular strengths of French biotechnology research, scientists, and officials cited French research involving monoclonal antibody techniques and the development of transgenic plants. When queried about French weaknesses, our interlocutors mentioned the poorly developed state of microbiology and lags in biomolecular research.

On the industrial side, three giants--Rhone-Poulenc, Roussel-UCLAF, and SANOFI--dominate French biotechnology. Rhone-Poulenc, entirely state owned, recently bought the U.S. pharmaceutical manufacturer Rorer (for F19 billion), and, through its Merieux subsidiary, the Canadian firm Connaught Biosciences (F4.9

billion). Hoechst, the German Pharmaceutical giant, has controlled Roussel-UCLAF has since 1974.

Government Support for Biotechnology. According to officials at the Ministry of Research and Technology, total public funding of biotechnology research in 1990 is approximately F1.6 billion ($280 million). The majority of basic research in France is conducted at government research agencies, and biotechnology is no exception. Research in biotechnology is concentrated in five organizations--National Center for Scientific Research (CNRS), National Institute for Agronomic Research (INRA), National Institute of Health and Medical Research (INSERM), Pasteur Institute, and Atomic Energy Commission (CEA).

National Biotechnology Program. A national program of biotechnology, under the auspices of the Ministry of Research and Technology, is responsible for coordinating national research policy and planning in biotechnology among the various government ministries, research organizations, and universities. In 1990-91, it will disburse about F25 million ($4.4 million) in incentive grants designed to provide supplementary equipment and personnel to existing laboratories. The program's specific aim is to encourage collaboration between industry and public research institutions. Five priority areas of research have been defined:

1. Microbial genetics - microbiology and microbial physiology, use of molecular biology and immunology to identify, characterize, and improve strains of technological interest; applications of novel micro-organisms

2. Protein engineering - post-translation modification of protein structure, purification and proteins; recombinant DNA techniques

3. Immunological and cellular genetics - constitution of immunoglobulins in micro-organisms, genesis, and modification of ctalytic properties or antibody recognition; intercellular communication

4. Plant and animal biotechnology - techniques of plant cell regeneration, use of cellular and molecular techniques to study morphogenetic mechanisms; transgenic animals, physiology of reproduction; cellular and molecular biology of embryonic development

5. Databases related to biotechnology.

The Ministry of Research and Technology also provides credits for biotechnology incentive programs in agriculture providing seed money for cooperative research with private industry.

Links with Industry. According to the Assessment of the Sautier Report, the diffusion of discoveries and technologies from public research organizations and universities to the private sector is more effective in countries such as the U.S. and Britain than it is in France. Several mechanisms to encourage technology transfer exist in France. Nevertheless, the links between public research and industry are considered inadequate, particularly so in the biological sciences. The number of different mechanisms that has been attempted in France attests to the difficulty of fostering such types of cooperation.

International Cooperation. French researchers participate in the two principal European Community (EC) research programs involving biotechnology:

1. Biomolecular Engineering Program (BEP), now replaced by the Biotechnology Action Program (BAP)

2. Biotechnology Research for Innovation, Development, and Growth in Europe (BRIDGE).

France also participates in two other EC programs--the program on Food-Linked Agro-Industrial Research (FLAIR) and the European Collaborative Linkage of Agriculture and Industry Through Research (ECLAIR).

France is also an active participant in the EUREKA program; French researchers participate in about half of the approximately 40 EUREKA projects involving biotechnology.

In international cooperation, there is a cooperative research agreement with Canada specifically in biotechnology, and there are broader agreements that include biotechnology with Japan, Brazil, Australia, and the Peoples Republic of China (PRC). Notwithstanding the political difficulties, the PRC is considered a promising partner because of its well-developed collections of agricultural strains.

Italy

For further information on Italian items, contact Reno Harnish, Office of Science Counselor, American Embassy, Rome, APO New York 09794-9500.

Italy's High-Technology Exports Decreased During the 1980s

The Italian National Agency for Nuclear and Renewable Energy (ENEA), with the support of the National Research Council, has recently completed a study on Italian competitiveness in industrial high-technology. The ENEA study compares data of the 1980-1981 period with those of 1986-1987. Furthermore, the study notes a general deterioration in the Italian position without any signs of an early reversal. In the former period, the exports of high-technology goods equalled 81.7 percent of imports of such goods. In the latter period, this percentage decreased to 65.5 percent.

According to the ENEA study, Italian industry is still considered competitive and expanding in only limited areas. In the 7-year period under consideration, the sectors that were weak in 1980 made some progress and those that were advanced regressed; consequently, the

level of technology in Italy has declined. During the same period, the international demand for high-technology has increased 13.4 percent, the average gross national product (GNP) of industrialized countries rose 7.7 percent, world trade increased 6.4 percent, and the exports of industrialized countries rose 5.8 percent.

The ENEA study reviews eight high-technology sectors: machine tools (MT), computers or automated machines for data elaboration (AME), telecommunications (TEL), commercial electronics (CE), electronic components (EC), aeronautics (AER), electrical and electronic instruments and devices (EEI), and chemicals and pharmaceuticals (CHE). In the period studied by the ENEA report, Italy's high-technology imports rose 17.9 percent while high-technology exports leveled off at 13.6 percent of total exports. In the 2-year period 1986-1987, high-technology imports were estimated at 12.478 billion European Currency Units (ECU) (1,515 billion lire or about $1.2 billion), while exports were 8.179 billion ECU with a commercial deficit of 4.299 billion ECU.

There are niches in which Italy is internationally competitive. Out of 174 products belonging to the 8 sectors under observation, there are 56 products that in the 1986-1987 period presented a positive balance for Italy in the high-technology exchange. Italian success in these niches does not offset the report's larger conclusion, because only eight of these products account for more than 100 million ECUs. Italy's high-technology export share within the EC from 1980-1987 rose from 9.5 percent to 9.8 percent. Consequently in that period, the EC countries lost sizeable shares of the world market to Japan and emerging Asian countries. In addition, according to the ENEA report, less than 10 percent of total Italian high technology production is successful in those international market areas experiencing rapid growth in demand.

The ENEA attributes this declining competition to the Italian government's and industry's low investment level in research. In 1987, this investment was 1.28 percent of the GNP and in 1988 was estimated to reach 1.40 percent. This was still far from the healthy 2.5 percent that would make Italy's scientific research effort comparable to that of other Western European countries. For instance, private industry from 1979-1989, only increased its research investment about 10 percent.

The ENEA concludes there is a pervasive difficulty in producing and selling Italian high-technology products. Some sectors are in particularly dire straights, such as chemicals and pharmaceuticals, electrical and electronic instruments and devices, and even computers. The ENEA writes that the only hope for a change from the present status of affairs lies in the expansion in international markets of those niches or individual successful products included in each of the sectors under study. The ENEA believes that unless adequate government policy and support is adopted soon to favor Italian high-technology development, the future of industry in this area is uncertain.

Technology Roundup - Italy

Roundup of the First 6 Months of the Italian Presidency of EUREKA. The Italian Minister of University and Scientific Research reviewed the first 6 months of the Italian Presidency in the European Research Coordination Agency (EUREKA). During this period, EUREKA officials approved 14 new research--5 for robotics, 5 for environment, 2 for informatics, and 2 for biology at a total cost of about 120 billion lire (about $96 million). Italy participates in six of these projects with a financial commitment of 21 billion lire or 27 percent of the total financial commitment. During this period, a policy routine was established to approve the new projects by experts in meetings to be held every 3 months.

Scientific Cooperation Between Italy and the Soviet Union. The University of Genoa and the Soviet State Committee for Science and Technology have started a joint center for advanced research in biotechnology and bioelectronics located on the Island of Elba. The EC is financing the project aiming to develop transistor-molecules capable of eliminating limits to miniaturizing. These limits are imposed by using inorganic material. In a meeting in Rome, scientists of the University of Bologna and Florence and the Director of the National Research Council agreed to cooperate on a project on fine chemicals. Nicolai Platé, Director of the Research Institute for Petrochemical Synthesis,led the Soviet delegation. Delegates selected 11 chemical research projects, such as catalytic systems for organic reactions, synthetic films for separation of liquids and gases, and polymeric liquid crystals. When the Italian delegation visits the Soviet Union in June, delegates will complete the agreement.

Superconducting Cyclotron Being Installed in Catania. The National Institute of Nuclear Physics is installing a superconducting cyclotron within its facilities in Catania. The cyclotron will be operational in 1991, and for its features and size will be the first in Europe and third or fourth in the world. This project was started in 1981 and its estimated total cost is 20 billion lire (about $16 million). The term superconducting is applied to this cyclotron because it employs coils made of a niobium-titanium alloy immersed in liquid helium at a temperature of -269°C. These superconducting coils make it possible to obtain magnetic fields of 5 tesla and to make the accelerator less expensive and more compact. The outside diameter of the magnet is only 3.8 meters. The cyclotron will be used for the acceleration of heavy particles.

The Bologna Robotic Hand. Researchers in the Department of Engineering at the University of Bologna, in cooperation with the high-technology school of the University of Pisa, have demonstrated a highly skilled

robotic hand at a recent meeting held in Pisa. The hand is capable of carrying on several functions of different sensitivity like picking up a billiard ball, a pin, or a feather without crushing them or letting them fall. The hand can hold a pencil with its fingers, take a bottle or a glass, and pour water from one to the other. This sophisticated hand is a second generation product and its inventors at the University of Bologna announced that they are working on a hand of the third generation that should be ready in 2 years. This hand should be able to reproduce very closely the functions and activities of a human hand covered with highly sensitive synthetic skin.

Italian Industry Participates in Manufacturing Space Suit. Italian industry will participate in the making of the European Space Agency (ESA) space suit with a share of 10 percent of the total commitment. The ESA space suit is expected to cost about 130 billion lire (about $105 million) and should be ready in 1999 for ESA astronauts aboard the HERMES Shuttle and the Columbus Space Station. The Italian industries involved in the manufacture of the space suit are: Aeritalia - one layer of the suit, Microtecnica - parts of the life support module on the back of the space suit, and Laben - the computerized system enabling the astronaut to control the management of the suit. The computerized system will be able to accept voice instructions from the astronaut and warn him through synthesized voice messages of the functioning of the suit. This highly automated system also can test the astronaut's physiological conditions and plan his mission tasks accordingly. Also, the system will monitor all the functions that are vital for the astronaut, and insert emergency programs in case of possible faults in these functions. The system also keeps the contact between the astronaut and his colleague on the shuttle or in the station. At the same time, it selects and prepares the data to be transmitted to earth.

Fast Train Program Taking Shape in Italy. The Fast Train Program, a reality in many Western European countries, is making a timid appearance in Italy. Starting June 1990, the train model ETR/500 began operating between Rome and Milan carrying 500 passengers at 300 kilometers per hour. Trevi Consortium of Fiat, Breda, Tecnomasio, Ansaldo, and the State Railways produced the train. The train uses new advanced materials, light alloys, and features a high degree of automation and electronic control. Another feature of this train is that (like the German ice and in contrast to the French TGV) it does not need a new type of rail to operate. However, Italy is the last among advanced nations to implement the high-speed train program. The program has an estimated cost of 18,000 billion lire (about $14 billion) through 1994 when 42 of these trains will travel in Italy.

Italy Needs Manager/Engineers. In Italy, the gap is growing steadily between demand and supply of engineers. Universities in Italy graduate a little over 6,000 engineers per year while industry demands 20,000. The dropout from the university course for engineers is the highest among all courses. Industry is seeing a type of manager/engineer who could develop and acquire those technologies that will lead to marketable products in the future. The Milan Polytechnic started in the early 1980s a course on managing engineering and in 1990, 130 of these engineers should graduate. The private Milan university Bocconi offers the same course, and public universities in Turin, Rome, Padua, and Naples will start the course soon.

New Ecological Diesel Motor. The VM Motori Company, based near Ferrara, has presented a new diesel motor called turbotronic. The motor's features that make it the most ecologically safe engine fuelled with either gasoline or oil. A four-cylinder, 2,500-cc, 136-hp engine, the turbotronic has a patented double swirl combustion chamber that allows the increase of power and the decrease of pollution. The motor features also a turbosupercharger and an electronic device called Rinox which manages the mixing of discharge gases and induction air so nitrogen oxides emissions are decreased. According to the President of VM Motori, the turbotronic is more ecologically safe than a gasoline-fueled engine equipped with a trivalent catalytic muffler, and has only a small emission of carbon dioxide. The research project cost 15 billion lire (about $12 million). As a result, the motor will be ready to market by mid-1991, costing about 450,000 lire (about $360) more than traditional diesel engines.

Fiat Spazio Established. The Fiat company has established Fiat Spazio which groups all Fiat companies interested in space like BPD Difesa Spazio, Gilardini, Fiat Avio, Teletra, and Comau. The new company intends to present proposals for complete space systems to be offered within Italy and abroad and is aspiring to become the first contractor for national and foreign commitments. The principal programs of the company are launches with Scout-type rockets, service modules in orbit employing autonomous propulsion units and vehicles for nonterrestrial use.

A Science and Technology Park for Porto Marghera. The Italian Chemical Company Enimont, with the support of the University of Venice, will establish a science and technology park in the area of Porto Marghera, formerly occupied by the Petrochemical Industry. The park will focus on:

- R&D of innovative polymers to be employed as new material in automobile, electronics, and furniture manufacturing
- Research to alleviate environmental problems caused by the chemical industry
- Identify and prepare low-cost new polymers to conserve and protect works of art.

The park will cost an estimated 20 billion lire (about $15 million) and will employ 70 researchers. To profit from the experience and expertise of similar foreign organizations, a team of Enimont officials visited Great Britain to learn about the management of British science and technology parks.

Interuniversity Consortium for the Physics of Matter. An interuniversity consortium for the physics of matter (INFM) is composed of 31 Italian universities with 1,165 researchers and 230 technicians. Professor Carlo Rizzuto, Physics Department, University of Genoa, heads the consortium. The consortium was created in 1987 to close the gap in the physics of matter and innovative materials between Italian research and leading laboratories elsewhere in the area. Thus far, Italy has one-fifth of the average resources that Western industrialized countries dedicate to this field. For the 5-year period 1988-1990, an estimated investment of 305 billion lire (about $240 million) will be required. The major part of the funding will be absorbed by basic research, the building of advanced, large instruments necessary to this type of research and communication facilities to allow access to this instrumentation for all consortium researchers.

Environmental News Items. Aeritalia and Alitalia formed Samantha (Air Company for Advanced Monitoring of Nature, Territory, Habitat, and Agriculture) to safeguard the environment. The new company will be active in remote sensing, disaster relief, water pollution monitoring, aerial spraying for agriculture and health purposes, and fire fighting. Samantha will extend its activities to developing countries, especially in desert areas where its services will be useful.

For breaching implementation of environmental rules, European Court of Justice cited Italy four times out of 12 of such citations issued for the EC. In addition, the EC charged Italy with violating 40 procedures for environmental regulations. Thus Italy, with Belgium, is the most undisciplined member of the EC in the environmental area. The Italian Minister of Environment said that this situation exists because the Italian Parliament is slow in approving EC directives and in publishing regulations that would make the directives operational.

Italy objects to the Swiss proposal to create a nuclear waste storage on Piz Pian Grand, located only 4 km from the border with Italy. The Italian Minister of Environment asked to meet with responsible Swiss authorities, while the ENEA has established a committee of experts to review the possible consequences for Italy in case the Swiss project materializes.

In the center of Naples, drinking water contains a quantity of nitrates over that allowed by normal safety precautions. The city administration has ordered the free distribution of bottled mineral water to the elderly, children, and pregnant women. By May, environmental precautions will bring the quantity of nitrates in drinking water to an acceptable level.

Small- and medium-size chemical firms will form consortia to create incinerators to dispose of industrial chemical waste. The Italian Chemical Industry Association (Federchimica) approved the creation of a financial holding company that will supply money and expertise. The wish to create a better public image for the chemical industry inspired the Federchimica initiative.

The Piedmont region has just approved a law to employ convicts in environmental work like reforestation, managing dump sites, cleaning up of river banks, and occupational duties in water treatment plants. The region has about 2,000 convicts and can employ about one third of them in environmental duties with a daily pay of 45,000 lire (about $35).

The Italian Minister of Environment said that Italy has 10,000 billion lire (about $8 billion) to spend on environment in the next 3 years. Of this amount, the Ministry of Environment will spend 4,700 billion lire in 10 different general programs with the Interministerial Committee for Economic Programming indicating individual financing.

Italian-Yugoslav Cooperates in Monitoring Adriatic Sea. During a recent bilateral meeting held in Yugoslavia, Italian participants described space activities that would help to safeguard and monitor the Adriatic Sea. Italian company Telespazio presented a project of Adriatic monitoring through LANDSAT, SPOT, and MOS satellites, costing 20 billion lire (about $16 million) for 30 months. Data collected by oceanographic ships, aircraft, observation points, and coastal monitoring stations will supplement the space resources. Although they discussed no financial commitments, the Yugoslav representatives at the meeting endorsed the project.

National Agency for Electricity Starts a Plan to Decrease Emissions from Thermoelectric Power Plants. The Italian National Agency for Electricity (ENEL) started a plan to meet the commitments taken with the July 1985 Helsinki protocol. The protocol establishes for 1993 a reduction of global emissions of sulphur dioxides of 30 percent over the quantities measured in 1980. The ENEL plan includes:

- Water desulphurizing
- Combustion systems emitting low nitrogen oxides
- Advanced systems for dust control and abatement
- Stations to monitor transboundary pollution.

Italian National Nightmare: The Adriatic Sea. With the approach of summer, the problem of Adriatic Sea pollution is a recurrent item in press, media, meetings, and symposia. The government made available 1,330 billion lire (about $1 billion) for 1989-1991. Three hundred billion lire went to regional administrations with coastal territory on the Adriatic, but 1,000 billion have not

been assigned to some meaningful goal through 1991. Adriatic problems are:

1. Abnormal blooming of algae because of hypernutrition caused by the influx of river water full of nitrogen, phosphorous, and organic compounds

2. Abnormal mucilage production last year covering a 10,000-sq km area caused by unknown factors.

The government approved a law to create the authority with the task of sketching a master plan for the safety and recovery of the Adriatic. This law assigns to the authority 84 billion lire (about $67 million) for 1990. Of the total, 69 billion will be used to build nets and partitions along the coast line to prevent the washing ashore of mucilage, 10 billion will be employed for scientific research, and the remaining 5 billion will develop a general plan to recover the Adriatic Sea. However, in the meantime, 1,000 billion lire (about $800 million) remain still unassigned.

In Italy, the environmental problem is not lack of money, but rather administrative inefficiency, bureaucratic procedures adopted to approve expenditures, and lack of clear vision and knowledge of the measures to be adopted.

Italian Government Finances Industrial Environmental Projects. Italian industry is focusing on new environmental technologies in all fields of activity and the Italian government has responded by financing individual projects. The Interministerial Committee for Industrial Policy (CIPI) approved partial financing for:

- Asbestos replacement in motor vehicle brakes
- Polluting agent abatement in dry cleaning
- Innovative electronic circuits that improve on energy conservation and environmental aspects.

The Ministry of University and Scientific Research will fiance four industrial projects with environmental content. The projects concern: research for a carbon monoxide sensor, copper recovery from molded circuits, new materials for building acoustic insulation, and a software package for environmental monitoring.

Olive Oil Wastewater Disposal. In the last 5 years, ENEL has invested 200 billion lire (about $160 million) in environmental improvement projects. One project concerns the disposal of wastewater obtained from olive oil presses by employing it in oil-fired powerplants. The intensive cultivation of olives in Italy produces over 500,000 tons of wastewaters from olive presses annually. Mixtures formed by oil and 5 percent wastewater allows a better combustion of oil resulting in a 60 percent decrease of unburned particles and sulphur compounds and a relative fuel saving.

Plastic Recycling Plants Search for Waste Plastic to Recycle. The Florence company, R. Ecoplast, can recycle heterogenous plastics at 300 kg per hour. The company is investing 2 billion lire and receives 649 million lire in government aid to launch two innovative processes to produce manufactured items from recycled plastic material. The company may recycle plastic with 10 percent of impurity and obtain a product called syntal which it can use as an alternative to wood. Syntal can be worked with the same machines that work wood and can incorporate dye for dark shades of color. Each year in Italy, an estimated 150 companies recycle 600,000 tons of plastic, but imports more than one third of this quantity. R. Ecoplast is idle most of the time because lack of plastic. Local Italian administrations did not implement rules for the differentiated collection of plastic from urban waste.

The Netherlands

For further information on Netherlands items, contact the American Embassy, Science Office, Economic Section, the Hague, APO New York 09159.

TNO Preparing for 1992

Introduction. The Netherlands Organization for Applied Scientific Research (TNO) is the largest applied science research institute in the Netherlands. The TNO is reviewing its research strategy and reorganizing in preparation for the added competition it will face from European institutes after 1992. With the completion of the internal market in 1992, TNO's position could be threatened when European research institutes can compete with it for Dutch government contracts. The TNO fears that unless it develops higher-quality programs, it will lose not only national government contracts but also contracts with international firms. The TNO is also rethinking its policy toward Eastern Europe.

Organizational Purpose. Established by an act of Parliament in 1932, the TNO is a private nonprofit organization that the government subsidizes. The TNO is administered independently and functions on a business-like basis. TNO's objective is to serve the Dutch society, government, and government policy in applied scientific research.

As such, TNO's revenues come not only from government subsidies but also from contract research and development (R&D) accomplished for third parties; i.e., small- to medium-sized Dutch business, multi-national Dutch firms, and international organizations.

Gross Turnover in 1988. In 1988, TNO's gross turnover was 625 million guilders (approximately $316 million). Third-party R&D contracts supplied 240 million guilders (f.) (approximately $121 million); central government contract R&D contracts supplied 85 million f. (approximately $42 million); and government subsidies supplied 300 million f. (approximately $152 million).

Reorganization in Response to 1992. In 1992, European firms and research institutes outside of the Netherlands can to tender for projects from the Dutch government. Thus, for the first time, TNO will face real

competition for government projects. This competition for national projects will come from European institutes throughout the European Community (EC). The TNO does not fear competition for work with small- to medium-size Dutch firms because these firms do not have the resources to switch easily from one institute to another. The TNO is concerned that its ability to gain contract work from the Dutch government and international firms could be threatened.

To meet these challenges, the TNO board of management is establishing a new research strategy and reorganizing its structure. Several of the 30 research institutes are being blended into larger, more powerful groups. Recently, the plastics and rubber research institute, the paint research institute, and the packaging institute were integrated into the TNO Center for Polymeric Materials. These institutes are being grouped to apply their knowledge efficiently to broaden the work programs offered to industry. In addition, TNO is taking these steps to develop higher-quality programs that will allow the organization to maintain its status even after the onset of European competition in 1992.

A Brussels Office for TNO. The TNO plans to detail specific employees to their soon-to-be-established Brussels office, as well as strengthen its ties with EC members.

The TNO is also developing more coordination on a central level for projects dealing with the Mediterranean EC countries. Because of centralized decisionmaking in these EC countries, TNO is developing an internal independent group (similar to the Bureau for International Projects) that deals specifically with projects in developing countries.

National Competition Growing as Well. The TNO is also facing growing competition within the Netherlands. This competition is coming from consulting firms with specialized knowledge. Consulting firms are organizing into groups like Netaconsult, a group of small consultancy firms working in the Netherlands and developing countries. Because these firms and universities are in the same field of work as TNO, there is often competition for national and international work.

However, there is also a lot of cooperation with these consulting firms and universities. The TNO works with consulting firms in various fields when these firms have specialized knowledge that is needed for certain projects. The TNO also coordinates closely with the Dutch technical universities in the country and has many joint projects with universities in Eindhoven, Twente, and Delft. As a research organization, TNO believes it is important for the organization to keep abreast of the latest developments. The TNO works mostly with the Technical University of Delft, and in fact, TNO's technical/physical laboratory is located at the university.

In certain fields, there is a working triangle consisting of TNO, universities, and industry. In microelectronics, the Center for Microelectronics (Center) is an example of such cooperative effort. The Technical Universities of Delft, Twente, and Eindhoven make up the Center's three research focal points. This setting allows for cooperative research and information exchange.

Projects with Non-OECD Countries. Each division within TNO is responsible for its own budget and national and international marketing. Projects with countries who are not members of the Organization for Economic Cooperation and Development (OECD) present circumstances so different from the industrialized world that it requires a special bureau. The bureau knows the cultural, social, and economic background of these countries to ensure efficient cooperation. The purpose of TNO's bureau for international projects is to guide and coordinate projects executed outside of OECD countries and to provide briefings on the countries for technicians and institute personnel before they go abroad.

In the past few years, the amount of contract work that TNO has received from the Ministry of Foreign Affairs (Ministry), which sets policy and allocates funds for projects with non-OECD countries, has increased from 11 million f. (approximately $5 million) in 1987 to 18 million (approximately $9 million) in 1990.

One reason TNO is successful in gaining these contracts is that the Ministry stresses work in the area of environment. The TNO is very professional and knowledgeable in this field, especially in the areas of water, air, solid waste, and policy formulation. Furthermore, TNO is very knowledgeable in energy and industrial safety which, like the environment, are important to non-OECD countries as they continue to industrialize. Another reason for TNO's success is a result of their status and relationship with the Dutch government and industry. The TNO has supported the government in making regulations and, in turn, supported Dutch industry in meeting these regulations. Therefore, TNO is familiar with the government's objectives and has the knowledge to fulfill the government's policy for developing countries.

International Cooperation Necessary. The TNO thinks that international cooperation is very important to the organization if it is to continue to be a force in the Netherlands. The TNO must work at the international level to keep its knowledge up to international standards. The Netherlands is too small for TNO to maintain its level of expertise on its own. Therefore, TNO works with institutes around the world, including in the U.S. The TNO has developed such good relations with U.S. institutes that some of these institutes represent them in Far East, particularly in technology for society.

In Europe, under the EC's BRITE/EURAM program which "aims at strengthening the technological base of traditional manufacturing industry in Europe by stimulating transnational collaboration," TNO and other contract research organizations have formed the European Asso-

ciation of Contract Research Organizations (EACRO). On February 25-27, 1990, EACRO held its first conference, sponsored by the EC's SPRINT program. Through this forum, the various contract research organizations throughout Europe are attempting to strengthen cooperation before 1992.

Eastern Europe Policies Being Rethought. Until now, TNO's policy forbade anyone within the organization from making contact with Eastern European firms without the Board of Management's special approval. Through the EACRO framework, TNO and the various EACRO members are considering programs with Eastern Europe.

The Netherlands Study Center for Technology Trends

Founded in 1968, the Netherlands Study Center for Technology Trends (STT) has been successful in certain areas of importance, according to STT's Director A.C. Sjoerdsma. For example, in 1971, STT studied the ways and means of energy conservation. The STT stipulated a doubling of oil prices and examined what a small country like the Netherlands would do in such a situation.

In 1973, when OPEC quadrupled the price of oil, STT presented the study and its suggestions to the Ministry of Economic Affairs. This presentation had a large impact on the energy world in the Netherlands and internationally. In 1973, the Ford Foundation established the "study of energy policy" project. Both the STT project and the Ford Foundation project were the bases of a large international exercise, over a 3- to 4-year period. The study resulted in three publications on world energy strategies which had an impact on energy consumption and use around the world.

The STT is the only center of its kind in the Netherlands. Other organizations in the Netherlands work on a contract basis or on subsidies allocated for specific projects. However, STT is a nonprofit organization that determines its own areas of interest.

The STT receives 1 million f. (approximately $500,000) annually in subsidies. The Royal Dutch Institute of Engineers in the Netherlands and the Ministry of Economic Affairs each provide one half. In addition, STT has a special arrangement with a large Netherlands publisher that publishes STT's studies at cost.

The STT has compiled 50 studies over the years, three of the most recent include:

1. New applications of materials (at the request of the European Commission; this publication was translated into English)
2. Knowledge-based systems that studies the application of artificial intelligence to industry; i.e., services, manufacturing, industry, medicine, and education
3. Limits to technology; a 20th anniversary study that investigates limits to technology and examines the possible answers.

Even though STT has been successful in forecasting some technical developments, neither STT nor individuals around the world continue to believe in the possibility of forecasting future technological developments. In fact, a few STT studies were overrun by the subsequent developments; i.e., a technology did not develop as expected or was not as important as STT believed. Instead, STT is trying to achieve a different, yet important, unofficial goal: the gathering of experts from a wide spectrum of disciplines to discuss developments in their fields and possibly add a new perspective and orientation to their work.

As emphasized by Director Sjoerdsma, the center is not an academic institute. Sjoerdsma said, "The center draws together experts from a broad range of disciplines who are the active leaders in their fields." These are individuals who are not only well versed in the theoretical foundations of their professions, but also on the practical day-to-day realities that their professions face and the responsibilities that they have to Dutch society.

The 18 members of the board of the study center exemplify the vast array of prominent Dutch individuals involved in STT. Board members are key individuals in the RIE, the Shell group, AKZO, DSM, professors from technical universities, sociologists, doctors, and lawyers.

For further information, contact

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